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ABSTRACT

This volume is the ninth in the biennial "Science Indicators" series initiated by the National Science Board. The series provides a broad base of quantitative information about the structure and function of United States science and technology and comparisons with other advanced industrial countries. An overview of science and technology for the United States of America is provided. Chapters included are: (1) "Precollege Science and Mathematics Education"; (2) "Higher Education for Science and Engineering"; (3) "Science and Engineering Workforce"; (4) "Financial Resources for Research and Development"; (5) "Academic Research and Development: Support, Personal, Outputs"; (6) "Industrial R & D and Technology"; (7) "The Global Markets for U.S. Technology"; and (8) "Public Science Literacy and Attitudes Toward Science and Technology." (YP)

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SCIENCE & ENGINEERING INDICATORS - 1989

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Cover Illustration

The illustration was supplied by Professor John H. Woodhouse, Department of Earth and Planetary Sciences, Harvard University. It depicts a section into the Earth showing a composite image synthesized from seismic tomographic mapping. Results from seismic tomography are being used to answer fundamental questions about the evolution and present-day dynamics of the Earth.

Lower than average velocities, which are indicative of elevated temperatures, are shown in orange; high velocities are shown in blue.

Details of the models and methodologies are available in Woodhouse and Dziewonski 1984 (*Journal of Geophysical Research* 89: 5953); Dziewonski 1984 (Ibid., p. 5929); Woodhouse, et al., 1986 (*Journal of Geophysical Research Letters* 13: 1549); and Morelli, et al., 1986 (Ibid., p. 1545).

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Letter of Transmittal

December 1, 1989

My Dear Mr. President:

In accordance with Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended, it is my honor to transmit to you, and through you to the Congress, the ninth in the series of biennial *Science Indicators* reports—*Science & Engineering Indicators—1989*.

These reports are designed to provide a broad base of quantitative information about U.S. science and engineering research and education and U.S. technology in a global context to be used by public and private policymakers in their decisions about these activities.

The data and analyses in this volume are especially important as our Nation seeks to define its priorities and programs in this era of rapid global economic, political, and social change. The key role of science and technology in achieving our national objectives is recognized by Government and industry, and is reflected in their support of this function.

This report follows its predecessors in providing basic information on U.S. and foreign:

- Research and development efforts, support, and performance;
- School science and mathematics education;
- Higher education for science and engineering;
- The science and engineering workforce;
- Technological innovation and high-technology trade; and
- Public science literacy and attitudes toward science and technology.

New features in this volume include materials on high school course-taking in science and mathematics, state support for R&D, "modeling" the science and engineering labor market, comparisons of U.S. and Japanese patenting in the United States, a "global" approach to analysis of data on production and trade in high-tech goods, and comparisons of U.S. and British public attitudes toward science and technology.

I join my colleagues on the National Science Board in expressing the hope that this report will be useful to your Administration, the Congress, and those concerned with formulating and analyzing science and technology policy.

Respectfully yours,

Mary L. Good

Mary L. Good
Chairman, National Science Board

The Honorable
The President of the United States
The White House
Washington, D.C. 20500

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Introduction

This volume is the ninth in the biennial *Science Indicators* series (ând the second entitled *Science & Engineering Indicators*) initiated by the National Science Board (NSB) in 1972. The series provides a broad base of quantitative information about the structure and function of U.S. science and technology (S&T) and comparisons with other advanced industrial countries. It is designed to both inform national policymakers who allocate resources to these activities and serve as an information resource to the S&T community at large.

The Basic Question of Science and Technology Policy

In this era of rapid global change, the Nation's key S&T policy concern is to identify the kinds, levels, and emphases of the national effort in science and engineering research and development (R&D) and education in order to:

- Produce sustained advances across a broad front in the understanding of natural and social phenomena (basic research);
- Foster vigorous inventive activity to produce continuing technological progress (applied research and development);
- Combine understanding and invention in the form of socially useful and cost-effective products, processes, and services (innovation); and
- Ensure an adequate supply of highly trained and talented scientists and engineers to meet the Nation's needs.

Creating Science and Technology Indicators

The science, engineering, and technology system is less easy to measure than other major functional areas of our society such as health, agriculture, or the economy. This is due in good part to the nature of its primary output—knowledge and ideas. People create, communicate, and carry ideas; dollars support people. We can and do track people and dollars. But we still are unsophisticated in our attempts to measure either science as a body of ideas or its connections with the social and economic order. Thus, our indicators remain—for now—largely measures of aspects of science and engineering *as sets of activities*, rather than as *particular bodies of knowledge*.

The elements of the science, engineering, and technology system in the U.S. can be specified as:

- The *human resources*, including working scientists and engineers and their technical support and technical managers and entrepreneurs;
- The various *organizational settings* for conducting R&D and technical education;
- The substantive *findings, research methods, and theories* embodied—in large part—in science and engineering literatures;
- The *physical infrastructure*, including research and teaching facilities and instrumentation with the most advanced capabilities;
- The necessary *financial support* for all of these elements; and
- A *cultural, economic, and legal context* that is supportive of these efforts.

While easy to specify in principle, describing each element and subelement in the system involves many problematic research issues. For example, what operational definitions should be used for counting scientists and engineers? Should it be their formal degrees? Their past work experience? Their current work activity? And, if all three, in what combination? In what sense do the data on U.S. patents awarded reflect rates of technical innovation? Does the dramatic increase in coauthorship of scientific publications reflect real change in the conduct of research?

Even more difficult are the problems of tracking and analyzing the interactions among these imperfectly measured elements—the dynamics of the system.

Continuing investigation into these questions is a *sine qua non* of improved indicators, and the National Science Foundation (NSF) does provide modest funds for extramural studies in this area. (See the Science Indicators Group Program Announcement, available upon request.) Descriptions of NSF-supported projects currently under way are available in *Project Summaries: FY 1987* (NSF 87-315).

About half of the quantitative information in this volume is generated by the national surveys and studies conducted on a continuing basis by NSF's Division of Science Resources Studies (SRS). The Division's *Publications List: 1978-1988* (NSF 88-335) details these studies; it also explains how to obtain detailed statistical tables from the various surveys (on computer diskettes), and data sets from the SRS Electronic Bulletin Board. Additionally, the *Publications List* references extramural publications deriving from SRS-supported studies. For further information, call (202) 634-4634.

This volume also contains considerable information obtained from outside NSF. The original sources are noted throughout the text and tables. In the case of analyses specially commissioned for this volume, the Science Indicators Group staff can provide further information. Call (202) 634-4682.

What Is New in This Volume?

Following the extensive structural changes in *Science & Engineering Indicators—1987*, the approach in the present volume has been to consolidate and refine those changes. However, a number of new features are also incorporated.

- A major new study of high school transcripts is analyzed in the precollege education chapter (chapter 1).
- For the first time, data about colleges and universities are broken out by the Carnegie categories of institutions in the chapter on higher education (chapter 2).
- A new "stock-flow" model for analyzing the dynamics of the science and engineering labor market is presented in the chapter on the workforce (chapter 3).
- The chapter on financial support for R&D includes a new section on state support for R&D (chapter 4).
- A new treatment of industrial support of academic R&D is included in the chapter on academic R&D, as is new bibliometric information on the growth of coauthorships of scientific papers (chapter 5).
- New comparisons of patterns of Japanese and U.S. patenting in the U.S. are presented in the chapter on industrial R&D (chapter 6).
- The title of the international chapter has been changed to "The Global Markets for U.S. Technology," reflecting a new approach to the area which includes U.S. internal markets for high-tech goods as an integral part of the analysis (chapter 7).
- The move toward international comparative materials on public attitudes towards science and technology, initiated in the 1987 *Indicators*, is continued in the present volume with comparative data from a parallel British survey (chapter 8).

Additionally, we have incorporated several new presentation techniques for enhanced readability and reader accessibility. These include "sidebar" stories accompanying the main text, changed Highlights formats, chapter-specific tables of contents, and a list of acronyms (appendix III).

Organizational Responsibilities

This volume is a collaborative effort, as can be seen in the acknowledgments below and in appendix II. The overall responsibility for the report derives from the statutory charge to the National Science Board [Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended]. A special committee of NSB members provided oversight and guidance to the staff of the Science Indicators Group of the Special Analytical Studies Section of the Division of Science Resources Studies, who worked exclusively on the report and related research. Other members of SRS, as well as staff from other NSF Directorates, aided in manuscript preparation. Numerous external expert reviewers and users helped to shape and sharpen the indicators. Overall staff responsibility for the report was assumed by NSF's Directorate for Scientific, Technological, and International Affairs.

Acknowledgments

The National Science Board extends its appreciation to the following members of the National Science Foundation (NSF) who provided primary assistance in the preparation of this report.

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The Board is also grateful to the special contributors to and reviewers of *Science & Engineering Indicators—1989*, all of whom are listed in appendix II.

Overview of U.S. Science and Technology

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Overview of U.S. Science and Technology

SYNOPSIS

The decade-long (1975-85) uninterrupted expansion of support for U.S. science and technology (S&T) has leveled off in recent years (1985-89). With some important exceptions, most indicators of U.S. S&T show significant slowdowns and downturns. For example:

- Growth rates have slowed in both research and development (R&D) funding and science and engineering (S/E) personnel.
- While the U.S. still spends more on R&D than the next four industrialized countries combined, some international competitors (e.g., Japan and West Germany) have drawn ahead of the U.S. in terms of R&D expenditures as a percentage of gross national product (GNP).
- In several areas, U.S. producers of high-tech goods have lost significant global market shares.
- National and international indicators of U.S. school mathematics and science performance show little improvement, despite continuing major reform efforts.
- U.S. university and college freshmen show a downward trend in their choice of undergraduate majors in some S/E fields. Although undergraduate S/E degrees awarded have remained at about 30 percent of all bachelor's degrees awarded for the past 3 years, the freshman shift away from S/E majors portends reduced S/E degrees in coming years.
- Increases in graduate S/E enrollments (in doctorate-granting universities) slowed from an average annual rate of 2 percent from 1980 to 1987 to a 1-percent increase from 1987 to 1988.
- Foreign students continued to increase (and U.S. citizens to decrease) their share of graduate S/E enrollments and S/E Ph.D. degrees granted by U.S. universities in all broad S/E fields except psychology.
- One area of continuing growth (albeit at a slightly slower rate than that of the past decade) is support for basic research and R&D in universities and colleges. This support has no doubt assisted the U.S. in maintaining its share of world scientific and technical literature.

Support for U.S. R&D continues to grow in constant-dollar terms, but at a much slower rate than has been the case for the previous decade and a half. Although total R&D expenditures grew at an annual rate of almost 6 percent from 1975 to 1985, the rate of growth for 1986 to 1989 is estimated at about 2 percent per annum.

The slower pace of U.S. R&D growth in recent years is also reflected in a U.S. lag of 3 consecutive years behind Japanese and West German R&D expenditures as a percentage of GNP.

The recent slowdown in funding growth is most dramatic for the development and applied research components of R&D (1-percent estimated annual growth rate from 1986 to 1989); basic research expenditures slowed only slightly to an estimated annual growth rate of 3 percent (in constant dollars). These trends are largely due to two sets of policy decisions. First, Federal S&T policy has moved toward reducing the rate of increase in defense R&D spending and toward maintaining growth in basic research and academic R&D. And in the industrial sector, corporate R&D decisionmakers have slowed their rate of growth in company funding of R&D.

While the U.S. continues to be the world's foremost supplier of high-tech products, its lead is shrinking. The U.S. share of global markets for high-tech goods, which declined during the 1970s and then recovered in the first half of the 1980s, showed renewed weakness in the latest period measured (1985-86). During this period, U.S. producers lost both domestic and foreign market shares. However, the U.S. trade balance in high-tech goods showed a slight upturn back into a positive balance in 1987; this followed a 7-year period of decline and a first-ever deficit in 1986. In terms of innovation, U.S. patent applications and awards—both indicators of a country's S&T innovation—have increased in the recent period, but not as rapidly as foreign patenting in the United States.

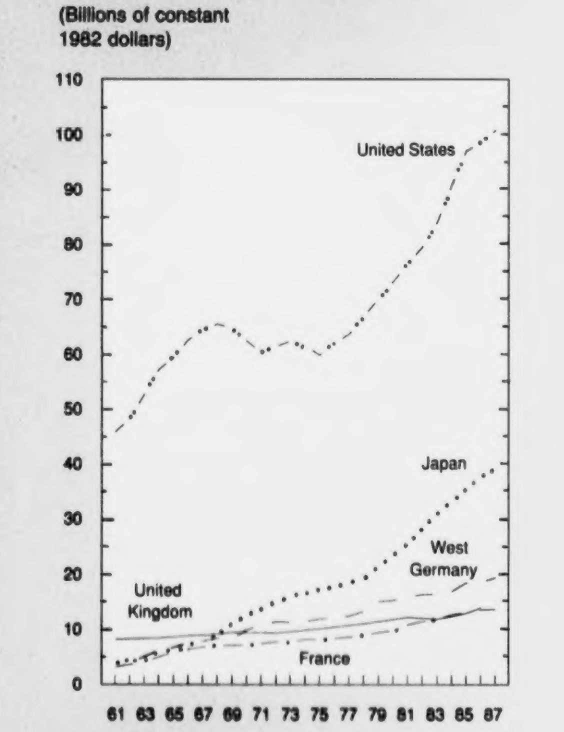
Since measurements began in 1957, the U.S. public has exhibited strong positive beliefs about the beneficial contributions of science and technology to society. Data from a 1988 survey of public attitudes toward S&T showed a reaffirmation of public confidence in the societal benefits of S&T. Previously, such confidence had wavered somewhat, as detected in two surveys conducted after the National Aeronautics and Space Administration space shuttle accident in January of 1986 and the Chernobyl nuclear plant accident the following May.

U.S. R&D INVESTMENTS IN A WORLD CONTEXT

In the world context, the United States spends more on R&D than the next four largest countries—Japan, West Germany, France, and the United Kingdom—combined. Over the past decade, the U.S. has more or less maintained its share of the combined R&D budgets of the five countries: 56 percent in 1975 versus 54 percent in 1986. This share was significantly reduced from the 68-percent share the U.S. enjoyed in 1966. (See figure O-1.)

Despite the differences in total expenditures, in 1987, the major noncommunist industrialized countries each invested approximately the same percentage of their GNPs in R&D. (See figure O-2.) Both Japan and West Germany have now exceeded the U.S. on this indicator for 3 years (1985-87).

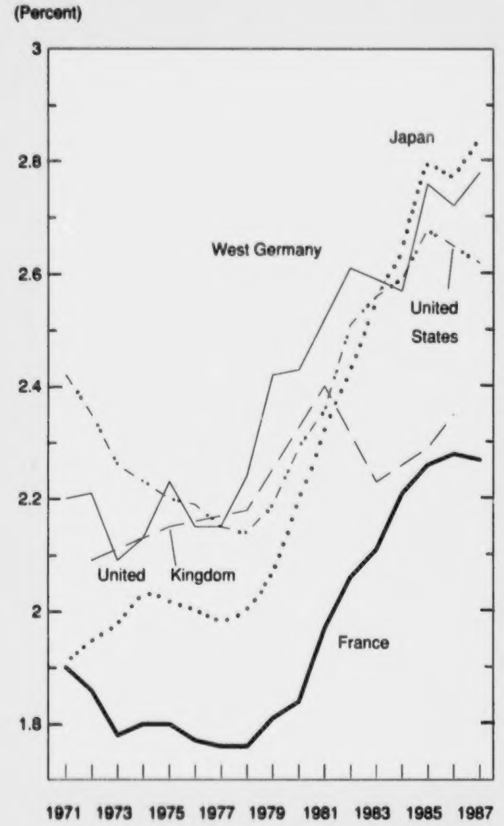
Figure O-1.
R&D expenditures, by country: 1961-87



Note: Some data are estimates.
See appendix table 4-19 and p. 96.

Science & Engineering Indicators—1989

Figure O-2.
R&D expenditures as a percentage of GNP, by country



Note: Data for some years are estimated.
See appendix table 4-19 and p. 96.

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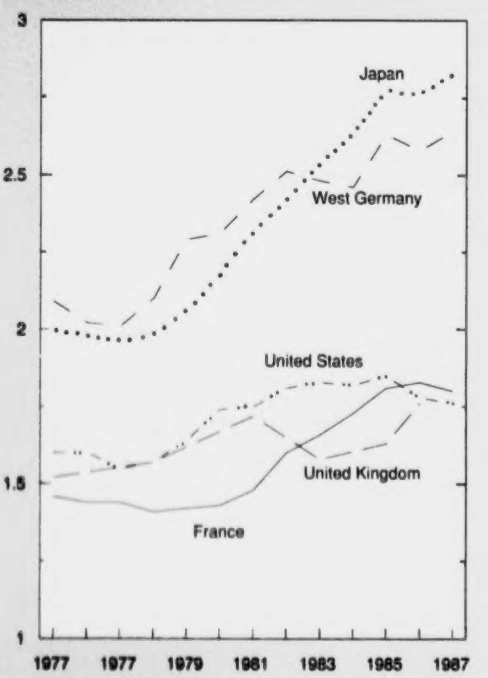
The nature of R&D investments has an important bearing on their economic contributions. If only nondefense R&D is considered, Japan and West Germany have been ahead of the U.S. for nearly two decades; additionally, their rate of civilian R&D investment as a percentage of GNP has been rising faster than that of the U.S. since 1981. (See figure O-3.) U.S. investment in nondefense R&D as a percentage of GNP has declined for at least 2 years.

The overall rate of increase of U.S. R&D expenditures has slowed considerably in recent years. While total national expenditures for R&D grew at an annual rate of almost 6 percent from 1975 to 1985 (in constant dollars), the rate of growth for the most recent period (1986-89) is estimated at only about 2 percent annually. The rapid rate of increase of development funding in the early 1980s has shrunk to an estimated annual rate of less than 1 percent in 1989. On the other hand, funding for basic research has continued to grow at only slightly less than its 1975-85 rate. (See figure O-4 and appendix table 4-5.)

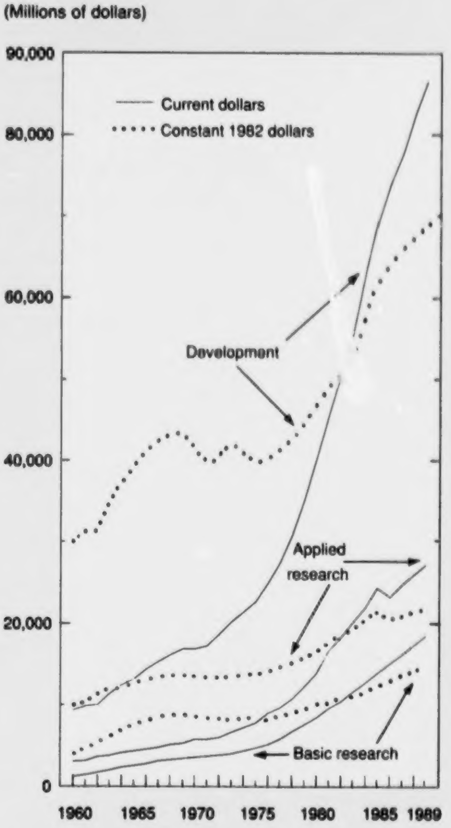
Changing growth rates in U.S. R&D expenditures are also evident in figure O-5, which displays defense and nondefense R&D by character of work. The massive increase in defense development expenditures from 1980 to 1985 was reduced to a very small growth rate by 1989. In civilian R&D, basic research maintained a significant growth rate in both periods, while civilian applied research and development expenditures remained approximately constant from 1986 to 1989 after suffering large cuts between 1980 and 1985.

Figure O-3.
Nondefense R&D as a percentage of GNP, by selected country: 1977-87



Note: Data for some years are estimated.
See appendix table 4-20 and p. 96.
Science & Engineering Indicators—1989

Figure O-4.
U.S. R&D expenditures, by character of work: 1960-89



Note: See footnotes, appendix table 4-3.
See appendix tables 4-3, 4-4, and 4-5; and p. 89.
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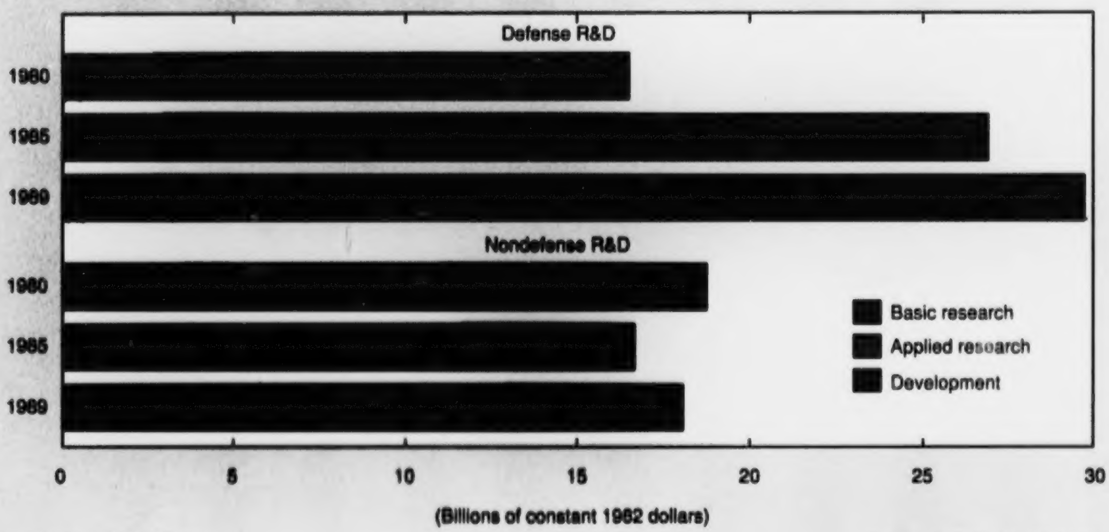
HUMAN RESOURCES

International Comparisons

Recent years (1984-86) have seen a slowing in the rate of growth of U.S. scientists and engineers engaged in R&D per 10,000 workers in the labor force. After two decades of rapid growth, Japan has now caught up with—and, in fact, slightly exceeds—the U.S. on this indicator. Japan has 67 researchers per 10,000, compared with 66 for the United States. France and West Germany continue to increase at about the same rate as the U.S., while in the United Kingdom, the growth of researchers in the labor force has remained flat since 1981. (See figure O-6.)

Figure O-5.
Relative changes in Federal obligations for defense and nondefense R&D, by character of work

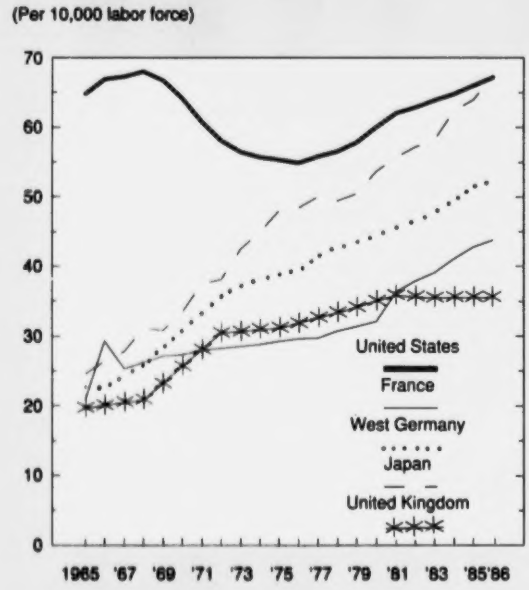


See appendix table 4-13 and p. 94.

Science & Engineering Indicators—1989

Closely paralleling the international comparative data on R&D funding, the U.S. in 1986 awarded more first academic degrees in natural science and engineering (NS/E) than the next four largest noncommunist countries combined—about 214,000 persons versus about 175,000, respectively. (See appendix table 3-18.) The five countries also vary considerably in the proportion of first academic degrees that are in NS/E fields, as well as in the relative proportions of natural science to engineering degrees. (See figure O-7.) The U.S. and Japan have the smallest proportions of all first university degrees in NS/E fields—20 percent and 26 percent, respectively—while France and the United Kingdom have the highest proportions (47 percent and 40 percent, respectively). Among the NS/E fields in Japan and France, first engineering degrees outnumber natural science degrees—in Japan, by a factor of four to one. In 1986, Japan—which has half the population of the U.S.—graduated about 73,000 engineers, a number almost equal to U.S. engineering degrees awarded in that year (77,000). In contrast, in both the U.S. and the United Kingdom, natural science degrees outnumber engineering degrees by nearly two to one.

Figure O-6.
Scientists and engineers engaged in R&D per 10,000 labor force, by country



See appendix table 3-19 and p. 76.

Science & Engineering Indicators—1989

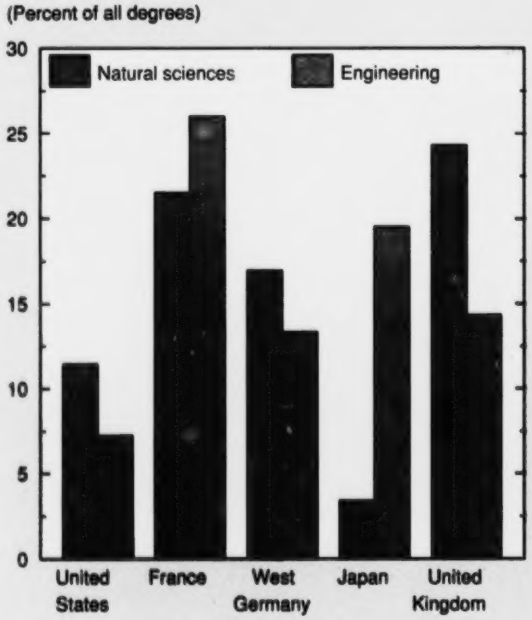
Private Sector Employment of U.S. Scientists and Engineers

Between 1977 and 1988, S/E employment in the private sector expanded at more than twice the rate of total employment.

This trend encompassed major changes in the occupational and industrial mix of S/E employment. For example, S/E employment in services-producing industries grew 103 percent over the period, compared to a 38-percent growth in total services employment. (See figure O-8.) S/E employment growth in the goods-producing sector stemmed from an increased share of a declining total in manufacturing jobs.

The expansion of the services-producing industries has been a key factor in the extraordinarily rapid growth of computer specialists between 1980 and 1988. (See figure O-9.)

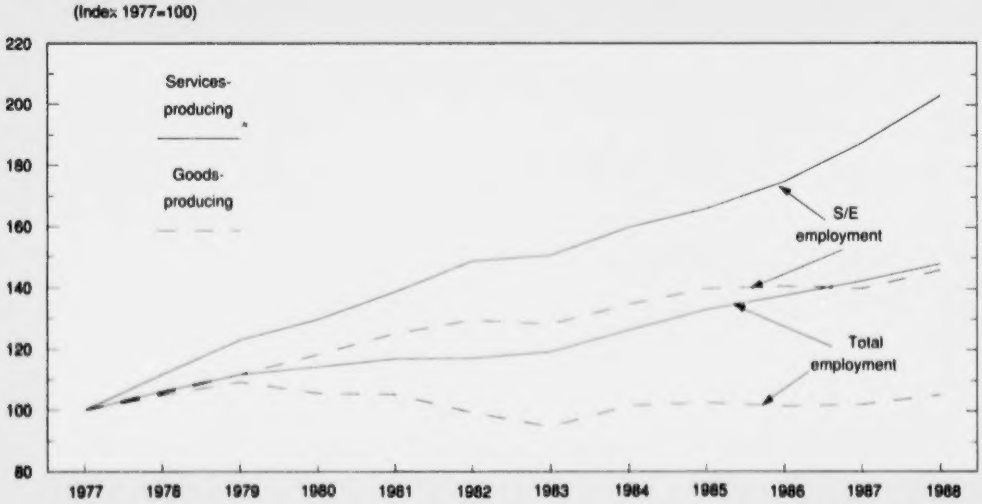
Figure O-7.
First university degrees, by field and country: 1986



See appendix table 3-18 and p. 82.

Science & Engineering Indicators—1989

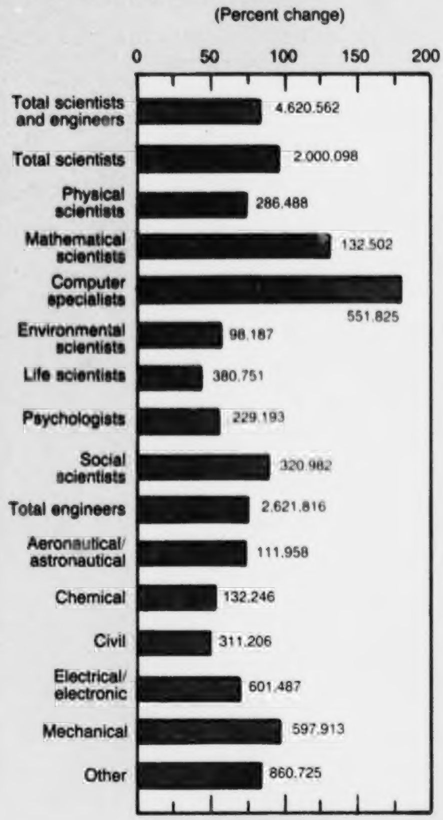
Figure O-8.
Index of S/E and total employment growth in private industry, by sector of employment: 1977-88



See appendix table 3-1 and pp. 63-65.

Science & Engineering Indicators—1989

Figure O-9.
Change in employment of scientists and engineers in S/E jobs, by field: 1980-88



Note: Numbers are for 1988 S/E employment
See appendix table 3-2 and p. 66.

Science & Engineering Indicators—1989

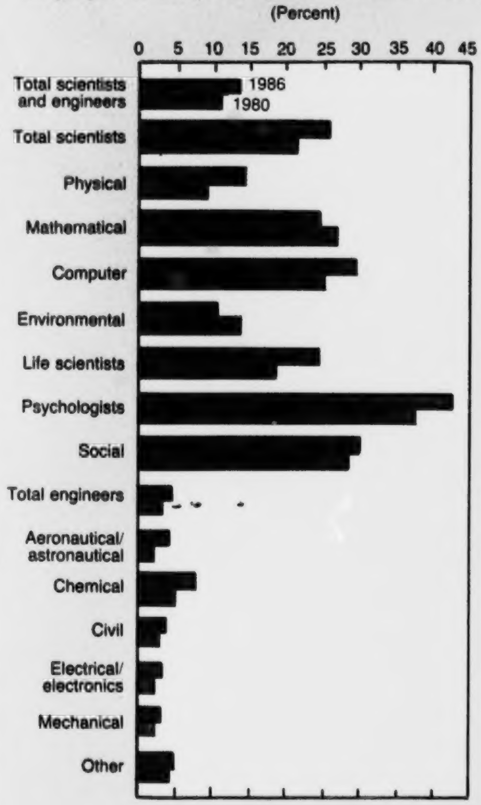
Women in S/E

Women scientists and engineers represented about 13 percent of the S/E workforce in 1986, up from 11 percent in 1980. (See figure O-10.) By field, women accounted for a much larger share of employment among scientists than among engineers—26 percent versus 4 percent. Between 1980 and 1986, women experienced small percentage losses in the mathematics and environmental sciences, but achieved sizeable gains in the physical and life sciences. Small percentage gains were made in all engineering subfields.

Precollege Science and Mathematics Education

U.S. school children continue to perform below the levels obtained by their age groups in other countries on science and mathematics achievement tests. In a 1988 international mathematics and science assessment of 13-year-olds in five countries and several Canadian provinces, U.S. children scored lowest of all the populations in mathematics and below the mean in science. (See figure O-11.)

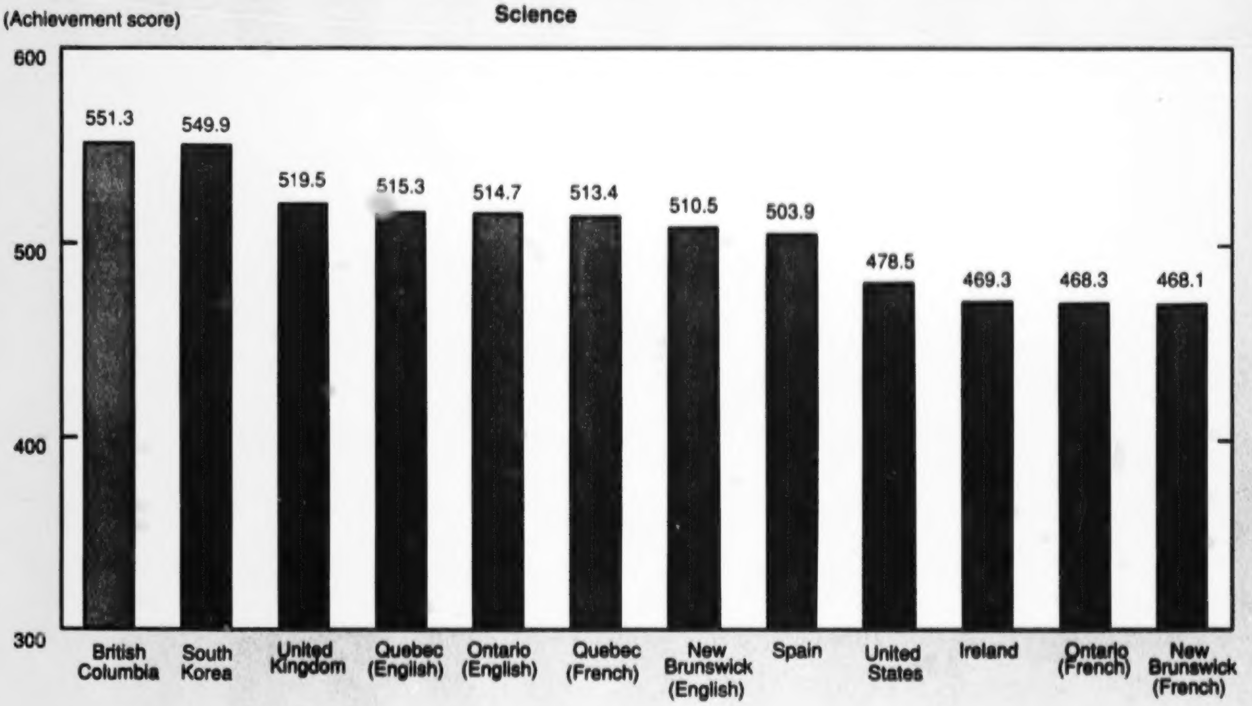
Figure O-10.
Women as a percentage of scientists and engineers employed in S/E jobs, by field: 1980 and 1986

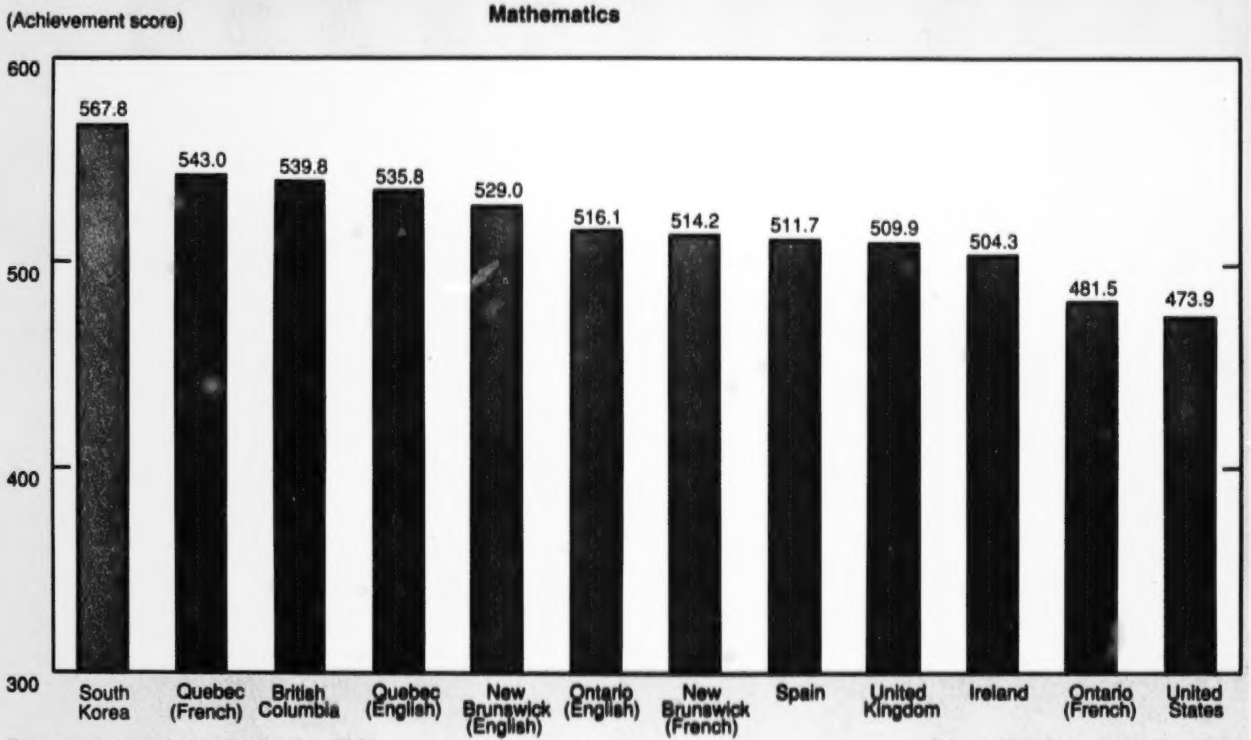


See appendix table 3-2 and p. 67.

Science & Engineering Indicators—1989

Figure O-11.
Average scores in science and mathematics achievement tests for age 13, by selected countries: 1988

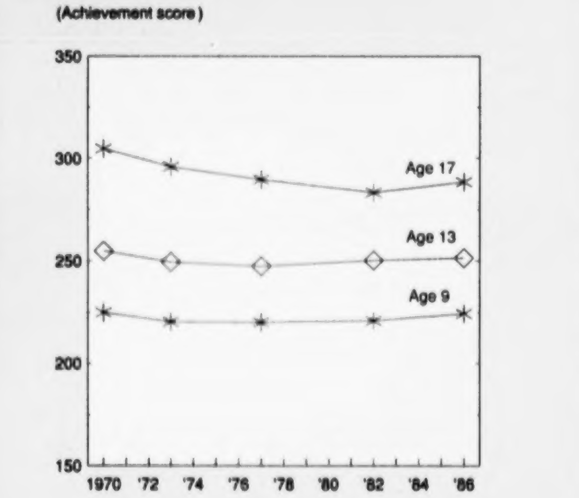




See appendix tables 1-11 and 1-12 and pp. 27-28.

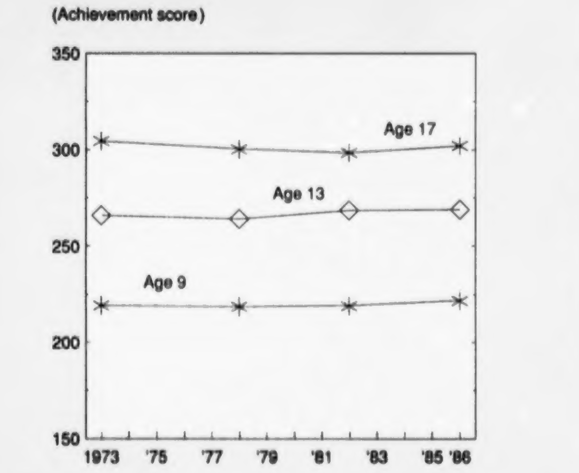
Science & Engineering Indicators—1989

Figure O-12.
National trends in average science achievement: 1970-86



See appendix table 1-1 and p. 22.
Science & Engineering Indicators—1989

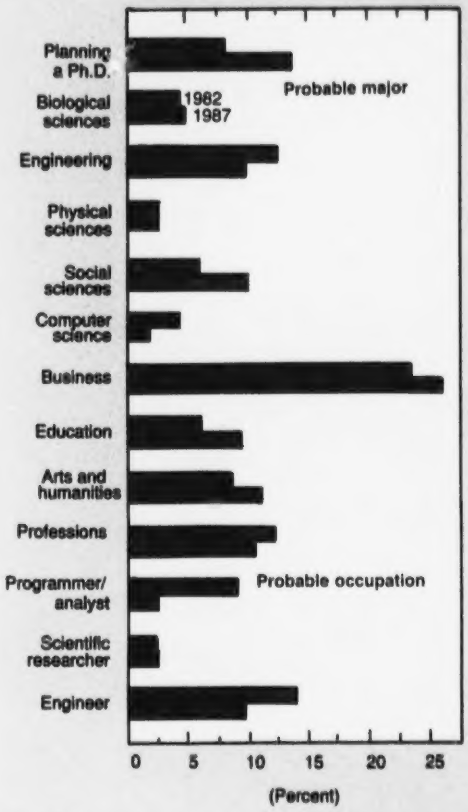
Figure O-13.
National trends in average mathematics achievement: 1973-86



See appendix table 1-6 and p. 24.
Science & Engineering Indicators—1989

There are signs, however, that the two-decade-long decline in mathematics and science achievement test scores of U.S. children may be turning around. Slight improvements in science and mathematics achievement trends were detected in the 1986/87 National Assessment of Educational Progress studies. (See figures O-12 and O-13.) Trends for 9-, 13-, and 17-year-olds across five national assessments in science since 1970, and four in mathematics since 1973, reveal a pattern of initial declines followed by subsequent recovery in all three age groups. In mathematics, 9- and 13-year-olds scored slightly higher in 1986 than in 1973. Scores for 17-year-old students, however, showed small declines. In science, the recent improvements have not yet brought scores up to their 1969 levels in any age group.

Figure O-14.
Freshman plans: 1982 and 1987



See text table 2-1 and pp. 50-52. *Science & Engineering Indicators—1989*

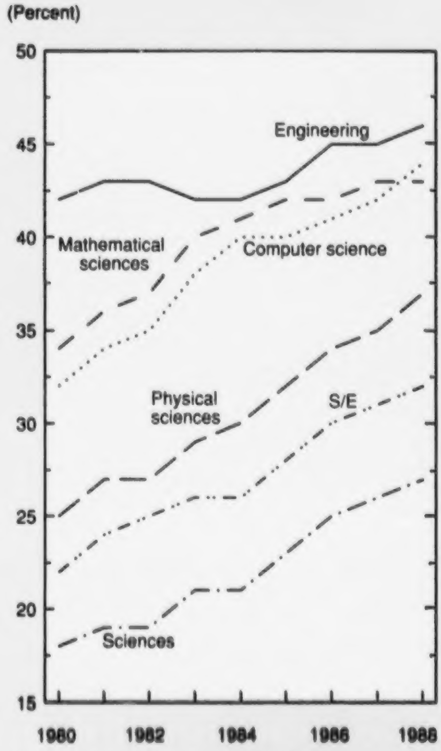
Higher Education

The interest of U.S. university and college freshmen in computing and engineering majors continues to decline. (See figure O-14.) However, a small increase in interest in a biological science major is apparent in the latest data, as well as renewed interest in the social sciences. Business, education, and the arts and humanities all register gains in student interest as evinced by choice of major.

While S/E degrees have remained about 30 percent of all bachelor's degrees in recent years, the downturn in freshman choice of S/E majors portends a reduction in S/E degrees in coming years. (See appendix tables 2-11 and 2-12.) Despite an increase in freshman engineering enrollments in 1988, decreases in engineering baccalaureates should continue for several years due to declining enrollments from 1983 to 1987. (See appendix table 2-5.)

At the graduate level, overall enrollments in science and engineering programs increased by 1 percent in 1988 over 1987, a significant drop from the 1980-87 trend of an average annual 2-percent increase. (See figure O-15.) Engineering, computer science, and environmental science enrollments show the most dramatic declines. However, several science fields experienced increased rates of enrollment. These included the life and social sciences, psychology, and mathematics.

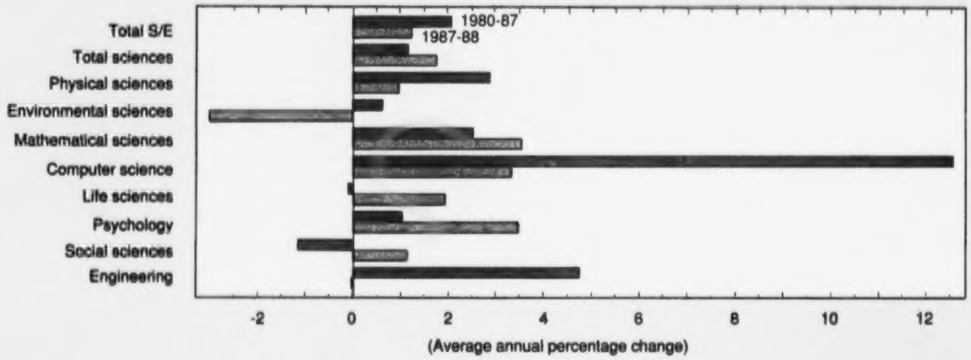
Figure O-16.
Foreign enrollment in S/E graduate programs: 1980-88



Note: Includes only full-time enrollment in doctorate-granting institutions. See appendix table 2-9 and p. 53.

Science & Engineering Indicators—1989

Figure O-15.
Change in graduate enrollments, by field



Note: Includes only enrollment in doctorate-granting institutions. See appendix table 2-7 and p. 53.

Science & Engineering Indicators—1989

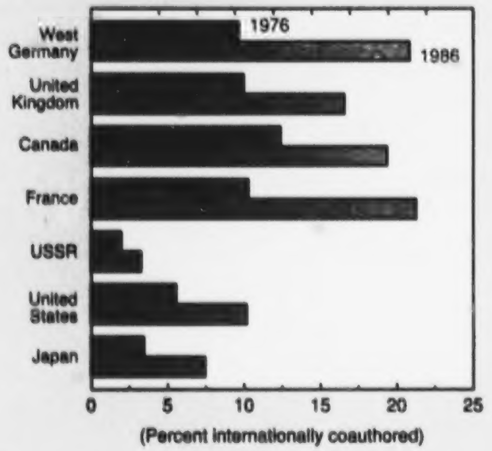
Text table O-1. U.S. share of world scientific and technical articles, by field: 1973, 1981, and 1986

	1973	1981	1986
	Percent		
All fields	38	36	36
Clinical medicine	43	41	40
Biomedicine	39	40	38
Biology	46	38	38
Chemistry	23	20	22
Physics	33	29	30
Earth/space sciences	47	43	43
Engineering/technology	42	41	37
Mathematics	48	38	40

See appendix table 5-23 and p. 120.

Science & Engineering Indicators—1989

Figure O-17.
Internationally coauthored articles, by country: 1976 and 1986



Note: An article is attributed to a country if one or more authors is from that country.
See appendix table 5-28 and p. 121.

Science & Engineering Indicators—1989

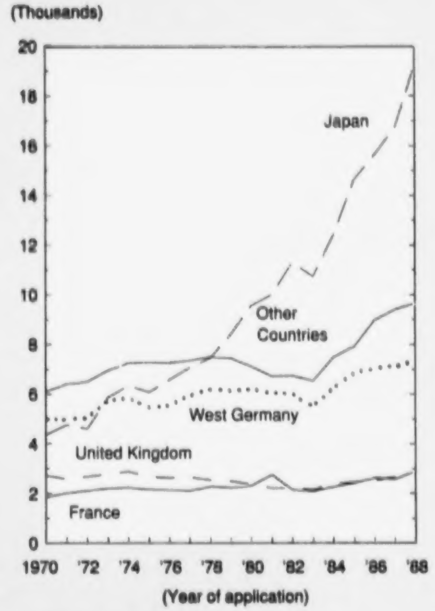
Growth in graduate S/E enrollments—albeit slowed—continues to be fueled by registrations of non-U.S. citizens. In doctorate-granting institutions, registration in graduate S/E programs of non-U.S. citizens accounted for the entire growth in total enrollments from 1987 to 1988. (See appendix table 2-8.) Non-U.S. citizens on temporary visas make up more than a third of S/E graduate students in engineering, mathematics, computer science, and the physical sciences. (See figure O-16.)

KNOWLEDGE CREATION AND APPLICATION

One measure of the relative strength of U.S. scientific research is the share of articles written by U.S. authors in the world's leading S/E journals. From 1973 to 1986, the U.S. more or less maintained its share of a little over one-third of world articles in most fields. Erosion of the U.S. share occurred in biology and mathematics—each of which lost 8 percentage points of its world share during this period. (See text table O-1.)

The data on international coauthorship of scientific articles suggest an increasing internationalization of scientific research. In the 1976-86 decade, most of the major countries studied virtually doubled the percentage of their papers coauthored with foreigners. (See figure O-17.) About 10 percent of all U.S. papers were coauthored with one or more foreign authors in 1986, as compared with about 6 percent in 1976. Western European countries ranged from 15 percent to 20 percent; Japan and the USSR had the lowest rates of foreign coauthorship.

Figure O-18.
U.S. patents granted to foreign inventors, by nationality of inventor



Note: Estimates are shown for 1981-88.
See appendix table 6-6 and pp. 135-36.

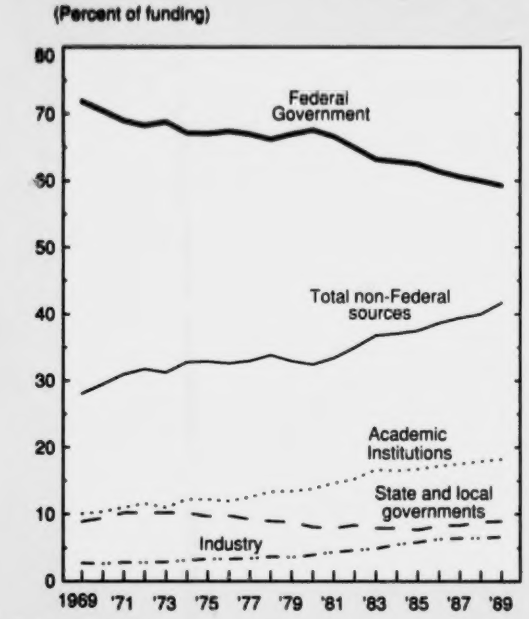
Science & Engineering Indicators—1989

U.S. inventors are increasing their numbers of successful patent applications in the U.S., but foreigners are acquiring U.S. patents at a significantly faster rate than are U.S. applicants. From application date 1970 to 1983, the annual number of U.S. patents granted to U.S. inventors fell from about 46,000 to 34,000, but has risen to about 45,000 in 1988. (See appendix table 6-6.) However, the proportion awarded to foreigners of all successful patent applications rose from 30 percent in 1970 to nearly half (48.5 percent) in 1987. Japanese inventors were by far the most active in increasing their U.S. patenting. (See figure O-18.)

RESEARCH AND DEVELOPMENT

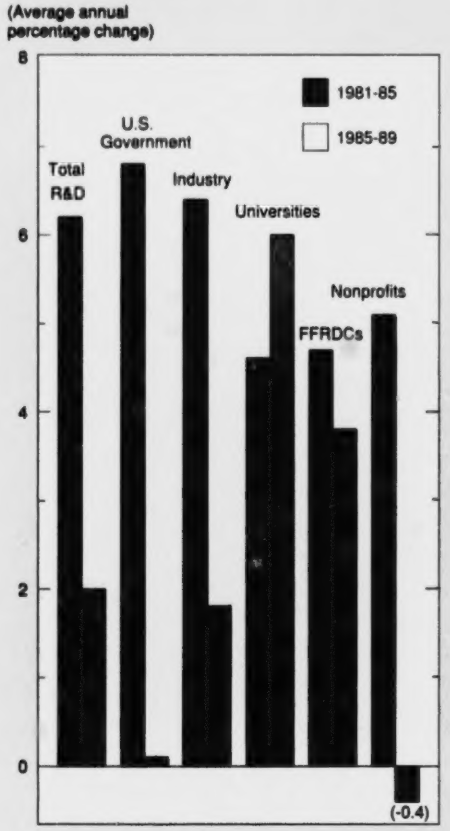
The relative magnitudes of the various R&D-performing sectors in the U.S. have stayed fairly constant over the decades, with some slight fluctuations. Industry has performed around three-quarters of all R&D, Federal laboratories and academic institutions around 10 percent each, and other entities around 5 percent. (See appendix table 4-2.) The very rapid growth of R&D in industry and government during the early 1980s has been replaced by growth rates of less than 2 percent in the late 1980s. Only the academic sector shows a higher rate of R&D growth in the late 1980s than in the earlier part of the decade. (See figure O-19.)

Figure O-20.
Source of academic R&D funding, by sector: 1969-89



Note: Data for 1988 and 1989 are estimates.
See appendix table 5-2 and p. 108.
Science & Engineering Indicators—1989

Figure O-19.
Change in U.S. R&D expenditures, by performer: 1981-85 and 1985-89



FFRDCs = Federally funded research and development centers.
Note: Some data are estimated.
See appendix table 4-2 and p. 87.
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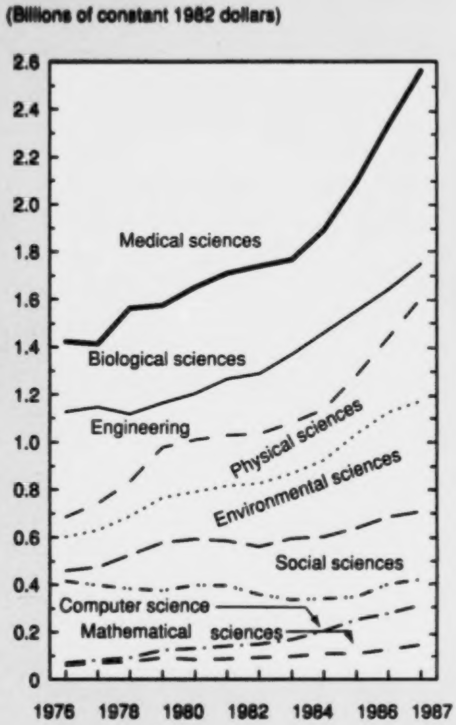
The continuing growth of academic R&D is being achieved (in some measure) with increasing support from non-Federal sources. (See figure O-20.) Institutional and industrial sources of support show a slow—but consistent—pattern of increased R&D funding over the past two decades, with quickening support in the 1980s. All fields of academic R&D have shared in this growth, but to differing degrees. (See figure O-21.) The most rapid rate of expansion of academic R&D expenditures has taken place in computer science, engineering, and the mathematical sciences, but the medical and biological sciences continue to lead in absolute expenditures.

Figure O-21.
Academic R&D expenditures, by field: 1976-87



See appendix table 5-9 and p. 111.
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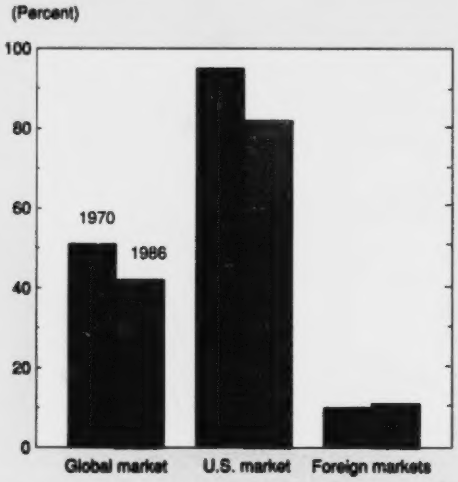
Figure O-22.
U.S. share of high-tech markets



See appendix table 7-8 and pp. 150-54.
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SCIENCE AND TECHNOLOGY IN THE MARKETPLACE

U.S. High-Technology Performance in Global Markets

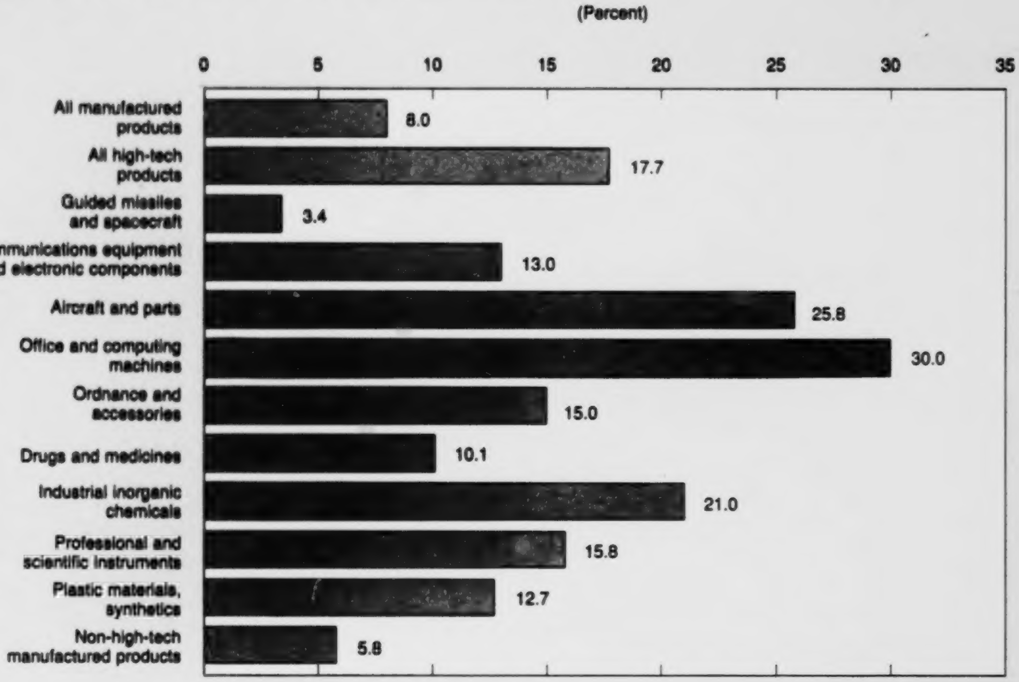
From 1970 to 1986, U.S. producers of high-tech goods decreased their share of global markets for such goods from about 50 percent to 40 percent. (See figure O-22.) However, almost all of this loss was due to a reduced share of domestic U.S. markets for high-tech goods. The share of world non-U.S. markets for U.S. high-technology producers actually increased slightly during the period.

U.S. producers of high-tech goods export about three times the percentage of their total shipments as compared with producers of non-high-tech manufactured products. (See figure O-23.) There has been little change over the past decade in the areas of high-technology where U.S. producers are most active in exporting. Aircraft and parts and office and computing machines remain the most export-intensive industries, and drugs and medicines, plastic materials and synthetics, and guided missiles and spacecraft the least.

Science and Technology in U.S. Industry

The latest estimates of U.S. industrial R&D activity show a flattening rate of increase of R&D expenditures after 1985. The previous decade (1975-85) saw continuous growth of industrial R&D from both corporate and Federal sources. (See figure O-24.) There was virtually no real growth in Federal funds for industrial R&D from 1985 to 1986. Company funds for R&D have continued to grow,

Figure O-23.
Exports of high-tech products as a percentage of shipments: 1986



See appendix table 7-9 and p. 153.

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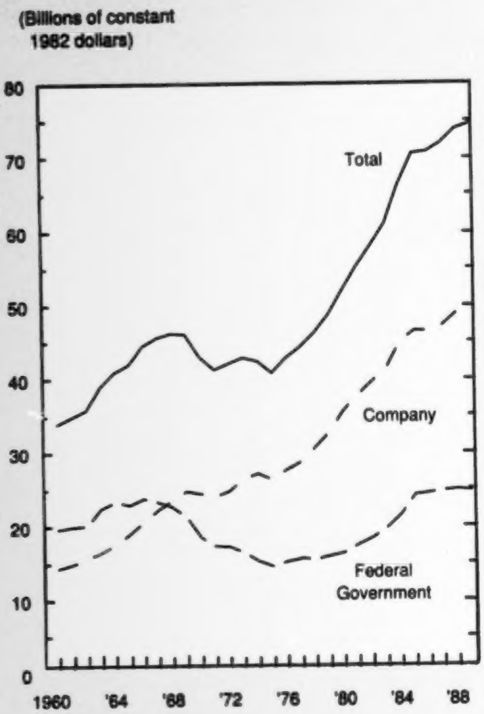
but at a much slower rate than during the decade before 1985.

During the 1975-85 decade, high-tech industries exhibited the bulk of the rapid growth in corporate R&D. Estimates for 1986 (the latest year for which industrial R&D data are available by industry) show a downturn in R&D expenditures (in constant 1982 dollars) in the high-tech manufacturing industries. (See figure O-25.) This trend may be slightly exaggerated—as may be the opposite upward trend in R&D expenditures among "other manufacturing industries"—by changes in the classification of certain major companies. But the principal finding of a slowdown in R&D expenditures among high-tech manufacturing companies is not in dispute.

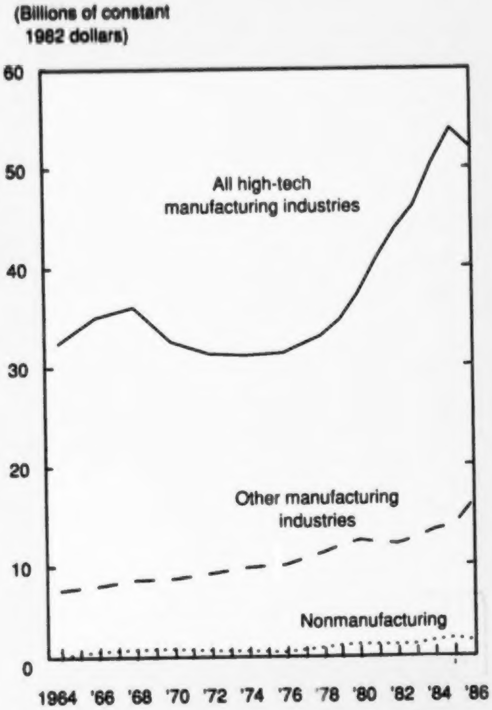
Through 1987, industry continued to increase its support of R&D in universities. (See figure O-20.) In that year, industry supplied a record high of 6.4 percent of total academic R&D funds. The continuing interest of corporations in university research is also reflected in the increased rate at which industrial and academic scientists and engineers collaborate in authoring scientific papers. (See figure O-26.) The percentage of all industrially authored papers which are coauthored with academic researchers almost doubled between 1976 and 1986 (15 percent and 28 percent, respectively).

Figure O-24.
Expenditures for industrial R&D, by source of funds



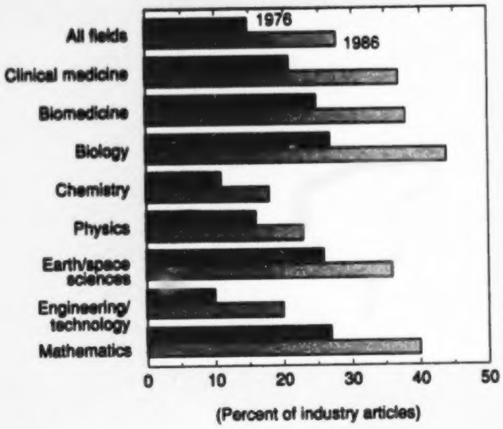
See appendix table 6-2 and p. 130.
Science & Engineering Indicators—1989

Figure O-25.
R&D expenditures, by industry group



See appendix table 6-3 and pp. 131-32.
Science & Engineering Indicators—1989

Figure O-26.
Proportion of industry articles coauthored with academic sector, by field: 1976 and 1986



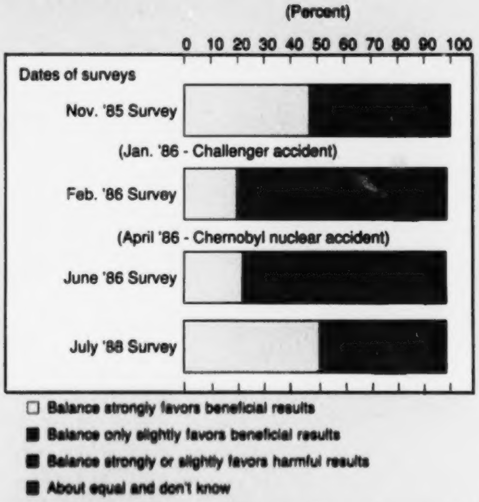
Note: All articles with one or more industry authors are counted as industry articles.
See appendix table 5-32 and p. 121.
Science & Engineering Indicators—1989

PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

Over the decades, the U.S. public has held a remarkably stable and optimistic view of the contributions of science to society. This stability persists even in the face of major technological accidents. Figure O-27 shows the changes in U.S. public opinion as reflected in surveys before and after the Challenger and Chernobyl accidents.

A fall 1985 survey showed the traditional finding that about three-quarters of the U.S. public believe that, on balance, the benefits of scientific research outweigh the harms to society. In addition, as in previous surveys, those who believe that the benefits "strongly" outweigh the harms outnumber those who believe that the benefits "only slightly" outweigh the harms by a margin of two to one.

Figure O-27.
Beliefs about beneficial versus harmful effects of scientific research: 1985-88



"Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or have the harmful results been greater than the benefits?" "Would you say that the balance has been strongly in favor of beneficial results, or only slightly?"

Note: The same persons were interviewed in the 1985 and 1986 surveys.

See appendix table 8-17 and p. 176.

Science & Engineering Indicators—1989

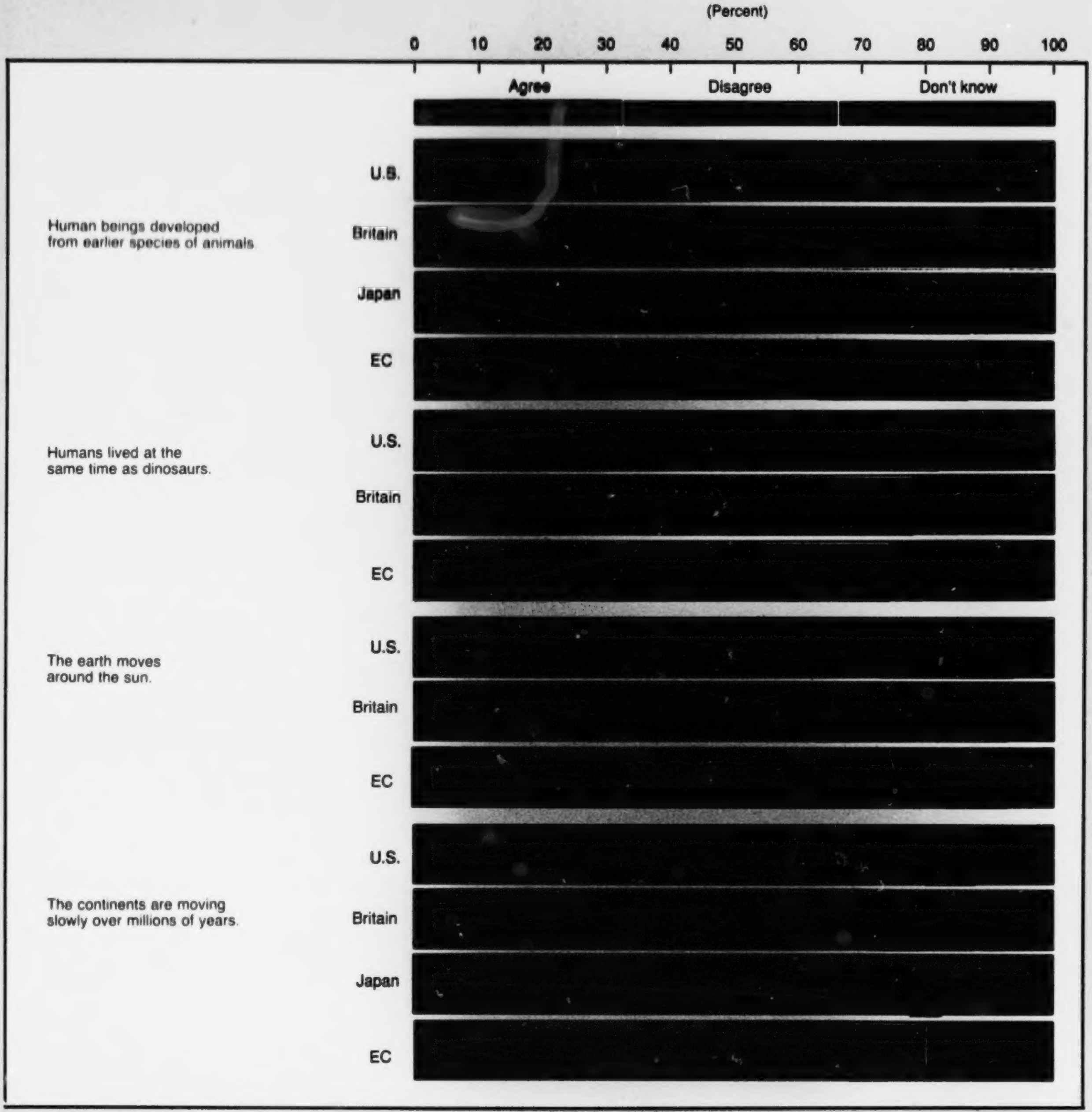
Two weeks after the Challenger accident on January 28, 1986, the individuals in the November 1985 survey sample were resurveyed. While the overall percentage acknowledging that the benefits of scientific research outweigh the harms remained about the same, there was a complete reversal of the percentages holding this view strongly or only slightly. This reversal was maintained when the same sample was questioned a third time in June 1986, after the Rogers Commission had completed its report on the Challenger accident, but also 6 weeks after a second major technological accident had occurred at the Chernobyl nuclear power plant. The results of the three surveys suggested that these technological disasters may have significantly eroded the strongly positive attitudes toward scientific research long held by the U.S. public.

However, a new national sample surveyed 2 years later in July 1988 showed that public attitudes had reverted to their pre-Challenger accident configuration—including both the overall positive assessment as well as the original pattern of the strength of the convictions.

Newly developed internationally coordinated surveys of public attitudes toward S&T are beginning to yield interesting national variations in public perceptions of and knowledge about S&T. Recent national samples of public opinion in the U.S., Britain, Japan, and the European Community (EC) show surprisingly similar patterns of knowledge and ignorance on scientific questions—with one major exception. (See figure O-28.) The British and the EC score a little better than do Americans on the question of the simultaneous existence of humans and dinosaurs; the U.S. and the EC score a little better than Britain on whether the earth moves around the sun. Large majorities in all three countries and the EC give the correct answer on continental drift.

On the issue of the evolution of the human species, however, the U.S. public differs markedly from the other samples. Less than half of the U.S. respondents agreed with the statement about evolution, as compared with 75 percent to 80 percent of the British and Japanese and 62 percent of the EC respondents. The U.S. pattern reflects a history of political and legal controversy on questions of biological evolution rooted in strongly held cultural or religious beliefs.

Figure O-28.
Public knowledge on selected scientific questions, by country



Notes: The U.S. and British data are from surveys conducted in the fall of 1988; the Japanese data are from a survey conducted in the winter of 1985; the European Community (EC) data are from surveys conducted in the 12 EC countries in the spring of 1989. For the precise question wordings, see the appendix tables cited.

See appendix tables 8-3, 8-4, and 8-7, and pp. 165-69. ***Science & Engineering Indicators—1989***

Chapter 1
Precollege Science and Mathematics Education

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Precollege Science and Mathematics Education

HIGHLIGHTS

Student Achievement

- *Following a wave of school reforms in the early 1980s, test scores on national science achievement tests have shown slight increases during the 1980s.* Achievement trends for 9-, 13-, and 17-year-old students from 1970 to 1986 show a pattern of initial declines followed by subsequent upturns for the three age groups. However, the recent improvements did not offset earlier decreases in test scores, and student scores in 1986 remained below 1970 levels for the three age groups. (See p. 22.)
- *Mathematics achievement showed a similar pattern, with students attaining slightly higher scores on national achievement tests in 1986 than in 1978.* While 9- and 13-year-olds scored slightly higher in 1986 than in 1973, scores for 17-year-olds were slightly lower. (See p. 24.)
- *In both science and mathematics, the largest increases in test scores occurred among the ethnic/racial groups that had performed comparatively poorly in earlier assessments.* For example, 9- and 13-year-old blacks and Hispanics showed larger gains in science test scores than did whites between 1977 and 1986, and the same findings applied to mathematics scores for 9-, 13-, and 17-year-olds between 1978 and 1986. (See pp. 22, 25.)
- *Despite these recent improvements, average black and Hispanic students were still far behind white students in achievement scores in 1986.* In 1986, the average 17-year-old black or Hispanic student performed at the same level as the average 13-year-old white student in the science and math achievement tests; the average 13-year-old black or Hispanic student performed at the average 9-year-old white student level in science. (See pp. 22, 25.)
- *In an international mathematics and science assessment of 13-year-olds conducted in five countries and four Canadian provinces in 1988, U.S. students scored lowest among the 12 populations in mathematics and fourth lowest in science.* South Korean students demonstrated the highest overall mathematics achievement, and British Columbian and South Korean students had the highest science scores. (See pp. 27-28.)
- *In another international science assessment, students at the 5th, 9th, and 12th grade levels in the U.S. performed poorly compared with their counterparts in other countries.* For example, among students taking a particular science course in their final year of high school, of the 13 countries tested, U.S. students placed last in biology, 11th in chemistry, and 9th in physics. (See pp. 28-29.)

Student Coursework

- *Largely as a result of school reform movements, the average number of courses U.S. high school students take in science, mathematics, foreign languages, and computer science has increased proportionally more than it has in other academic subjects.* Students took an average of one semester more of mathematics in 1987 than in 1982, and enrollments in advanced mathematics classes were up by about a third. Course-taking in science was also up, with the percentage of high school students taking a course in biology increasing from 75 percent in 1982 to 90 percent in 1987; increases also occurred in the percentages of students taking chemistry (from 31 percent to 45 percent) and physics (from 14 percent to 20 percent). (See p. 32.)
- *In the international science survey conducted in 1988, U.S. students spent less time on regularly scheduled hands-on activities than did any of the other 12 populations in the assessment.* While U.S. teachers believe that hands-on activity is the most effective method for teaching science, 38 percent of elementary school teachers reported that they use classrooms with no science materials or facilities, and less than half of secondary school teachers said they had access to a general-purpose science laboratory. (See pp. 34-36.)
- *The amount of time spent teaching science and mathematics in elementary school remained the same between 1977 and 1986.* In grades 4-6, science teaching averaged about 30 minutes per day, and mathematics teaching about 50 minutes per day. (See pp. 34-35.)

Teachers and Teaching

- *A 1986 study of the courses that science and mathematics teachers took in college showed that a substantial proportion failed to meet recommended standards for teacher preparation.* Only 34 percent of elementary school teachers who teach science met all of the standards of the National Science Teachers Association (NSTA). An even smaller percentage (22 percent) of grades 7-9 teachers of science met the full standards. At the high school level, 29 percent of biology teachers, 31 percent of chemistry teachers, and 12 percent of physics teachers met all of the NSTA standards. In mathematics, 18 percent of elementary school teachers met all of the National Council of Teachers of Mathematics' recommended standards, while only 14 percent of grades 7-9 teachers, and 15 percent of grades 10-12 teachers, met these standards. (See pp. 37-39.)
- *Among high school math teachers, 29 percent had taken no college math courses in the previous 10 years; the comparable figure for science teachers was 25 percent.* In a national survey conducted in 1986, teachers of science and mathematics said that they typically had spent less than 6 hours in professional development in these subjects during the prior 12 months. (See p. 39.)

A well-educated and trained workforce is essential to maintaining the Nation's domestic progress and world competitiveness, as well as individual progress and prosperity. Nationally, investment in education is one of the important sources of productivity and earnings. For example, recent studies indicate that, in the postwar period, increases in human capital have contributed 10 percent to 20 percent of real economic growth and a similar percentage of the gains in economic productivity. From an individual standpoint, workers with more schooling not only have higher earnings but also safer, more comfortable working conditions and lower rates of unemployment. For example, the unemployment rate for workers with fewer than 4 years of high school is double that of workers who completed 4 years of high school.[1]

The education system can be thought of as a "pipeline" through which students pass, increasing their educational level. Through elementary school and much of secondary school, nearly all students are part of this pipeline. But, as students make decisions about higher education, the pipeline diminishes in size. Particularly important is the period from 6th to 12th grade, when individual students make decisions about which courses to take—and not to take—which areas of the educational curriculum in which to specialize, and which careers to pursue.

As individuals make these plans about their academic future, they are influenced by a number of factors, including family and peer aspirations and motivation, the media, teachers and counselors, and testing practices.[2] Also, the content and quality of elementary and secondary education helps determine individuals' academic preparation for college, their likelihood of graduating from college, and their ability to derive the greatest benefit from a college education.[3]

Because the abilities, attitudes, and aspirations of today's elementary and secondary students directly affect the quality of the Nation's future college-bound population—and ultimately the skill of the Nation's human resources—several prominent and troublesome trends need to be examined:

- Despite recent improvements with respect to some age and ethnic/racial groups, both participation and achievement by U.S. elementary and secondary students in science and mathematics are lagging behind previous years and other countries.

- Participation of women and minorities in science and mathematics, although improving in recent years, still is below the average white male. Achievement of minorities in science and mathematics remains well below that of whites.

- Compared with students in other developed countries, American students demonstrate lower achievement in problem solving and higher-order thinking.

- Many students, particularly those in less affluent schools, are taught by teachers of science and mathematics who are not fully qualified. Shortages of fully qualified elementary and secondary school teachers are most apparent in physics, chemistry, computer science, and mathematics.

In the early 1980s, the widespread nature of these and other problems was drawn to the Nation's attention in a spate of national reports, all of which recommended extensive school reform. More recently, education leaders in all 50 states, as well as numerous local education agencies, have initiated activities to set standards for schools or students.[4] Among the specific problems identified were declining student performance, dilution of graduation standards, and a high school curriculum loaded with electives.

As a result of the numerous commissions and the recommendations contained in their reports, extensive reforms were launched, including, for instance, increasing the number of course credits required to graduate, regulating and standardizing curricula through state frameworks or guides and through the selection of textbooks, and testing for student mastery of basic skills and/or proficiency in subject matter areas.[5] The intent behind this broad range of policy initiatives was to raise student performance and exert some form of quality control over the process of education.[6] And while several national studies discussed in this chapter have shown some overall positive results in student achievement and student course-taking, many states are now in the process of conducting their own studies to evaluate the effectiveness of these reforms.

Structure of the Chapter

This chapter consists of three major parts, organized to discuss the indicators in the categories used by the National Research Council's (NRC) Committee on Indicators of Precollege Science and Mathematics Education.[7] The committee was charged with (1) developing a framework, as far as possible, using existing data to provide a baseline; and (2) suggesting what data and analyses will be needed in the future for a continuing portrayal of the condition of precollege science and mathematics education. The NRC committee defined the concept of an "indicator" as a measure that conveys a general impression of the state or nature of the structure or system being examined. While it is not necessarily a precise statement, it gives sufficient indication of a condition concerning the system of interest to be of use in formulating policy.

To identify the central concepts relevant to the science and mathematics education system, the committee modeled the educational system in terms of *inputs*, *processes*, and *outcomes*. The committee then recommended monitoring the following key schooling variables:

- *Inputs*—teacher quantity and quality, and curriculum content;

- *Processes*—instructional time/course enrollment; and

---

[1] Council of Economic Advisers (1988), pp. 166 and 170.

[2] OTA (1988a), p. 5.

[3] OTA (1988b), p. 3.

[4] Moyer (1987), p. 1.

[5] Ibid.

[6] Capper (1988).

[7] Raizen and Jones (1985).

- *Outcomes*—student achievement.

The committee considered student achievement to be the primary indicator of the condition of science and mathematics education, since the acquisition of knowledge is the main reason for the existence of formal education. Input and process variables were selected that research had shown to be related to student achievement; namely, exposure to a subject (instructional time/course content), the number and qualifications of teachers with instructional responsibilities in science and mathematics, and the opportunity to learn these subjects as reflected in the content of the curriculum.

This chapter presents most recent data on the above-discussed variables, arranged in accordance with the committee's proposed model of the education system. The chapter also reviews recent educational reform efforts that have been established to improve the quality of student learning, classroom instruction, teacher performance, and curriculum content.

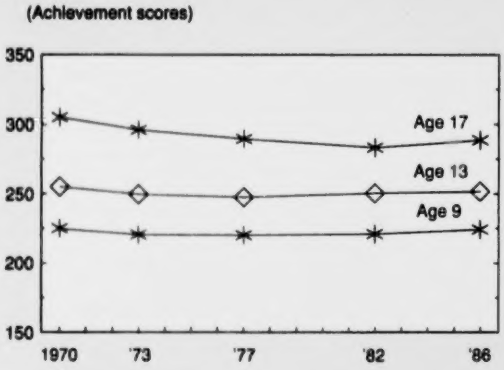
STUDENT ACHIEVEMENT[8]

In the 1985/86 academic year, the National Assessment of Educational Progress (NAEP) tested national samples of 9-, 13-, and 17-year-olds in science, mathematics, and—for the first time—computer competence. These results permit a 17-year trend analysis for five assessments in science (conducted in 1970, 1973, 1977, 1982, and 1986) and a 14-year trend analysis for four assessments in mathematics (performed in 1973, 1978, 1982, and 1986). Also, for the first time, the results in science and mathematics were scaled according to various levels of proficiency.[9]

Science Achievement

While overall trends in science achievement for 9-, 13-, and 17-year-olds across five national assessments from 1970 to 1986 do not reveal dramatic changes, they do show a pattern of initial decline followed by subsequent recovery at all three age levels.[10] (See appendix table 1-1.) These recoveries, however, have not yet compensated for the declines. Declines from the 1970 levels occurred in assessments conducted in 1973 and 1977, but these were followed by upturns in performance between 1982 and 1986. In 1986, however, average achievement at ages 13 and 17 remained below that of 1970; at age 9, average achievement just returned to where it was during the first assessment of 1970. (See figure 1-1.)

Figure 1-1.
National trends in average science achievement: 1970-86



See appendix table 1-1.

Science & Engineering Indicators—1989

Achievement by Minorities. Despite recent gains, the average achievement of both 13- and 17-year-old black and Hispanic students remains at least 4 years behind that of their white peers. (See figures 1-2, 1-3, and 1-4.) From 1977 to 1986, white students at ages 9 and 13 tended to show slight improvements; black and Hispanic students at these ages showed larger gains. Although all three ethnic/racial groups at age 17 improved from 1982 to 1986, only black students showed important gains across the 9-year span from 1977 to 1986. As a result of recent improvements, 17-year-old black students surpassed their 1977 performance in 1986, while Hispanic and white students did not.

Achievement by Females. At all three ages—but particularly at age 17—the science achievement of females in 1986 was below that of males, a trend that has persisted throughout the 17 years of assessments. The science performance of 9-year-old females in 1986 remained slightly below that of 1970, and the performance gap between males and females at age 9 has increased somewhat during that time. The performance gap between 13-year-old males and females consistently widened across the five assessments. At age 17, although the gap between the sexes continued, trends in performance were comparable for males and females: both groups showed steady declines in performance from 1970 to 1982 and improvements from 1982 to 1986. (See appendix table 1-1.)

Level of Student Proficiency in Science

Based on a review of the NAEP test items by science specialists, the NAEP results were used to describe five levels of student proficiency:[11]

---

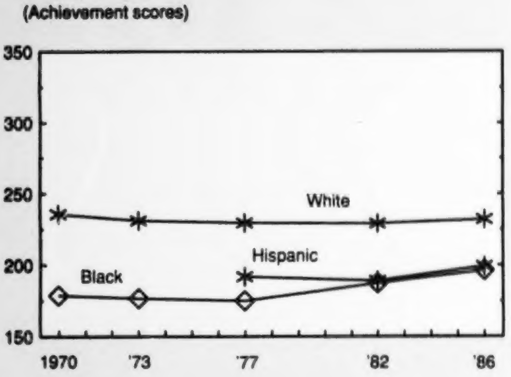
[8] The following information draws heavily on three reports published by the National Assessment of Educational Progress section of the Educational Testing Service under the heading "The Nation's Report Card." See NAEP (1988a), (1988b), and (1988c).

[9] Briefly, the statistical methodology used to develop these proficiency scales involved the computation of percentages of students giving various responses to the assessment items and using Item Response Theory (IRT) technology to estimate levels of science and mathematics achievement for the Nation and for various subpopulations. IRT defines the probability of answering a given item correctly as a mathematical function of proficiency level or skill and certain characteristics of the item. Each proficiency level is defined by describing the types of science and mathematics questions that most students attaining that proficiency level would be able to perform successfully. (See appendix tables 1-2, 1-7, 1-13, and 1-14.) Science and mathematics specialists examined these empirically selected item sets and used their professional judgment to characterize each proficiency level. For a detailed description of the statistical methodology used, see NAEP (1988a) or (1988b), pp. 132 and 141.

[10] NAEP (1988a).

[11] See footnote 9 and appendix table 1-2.

Figure 1-2.
Trends in average science achievement for age 9, by race/ethnicity: 1970-86

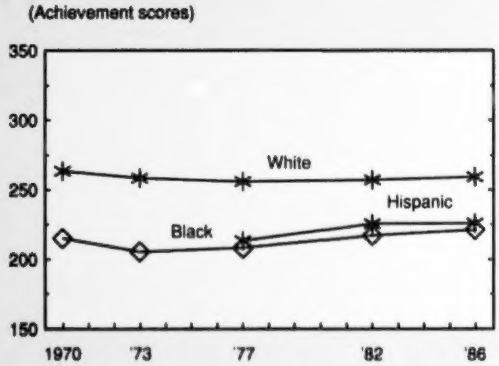


See appendix table 1-1. *Science & Engineering Indicators—1989*

- Knows everyday science facts.
- Understands simple scientific principles.
- Applies basic scientific information.
- Analyzes scientific procedures and data.
- Integrates specialized scientific information.

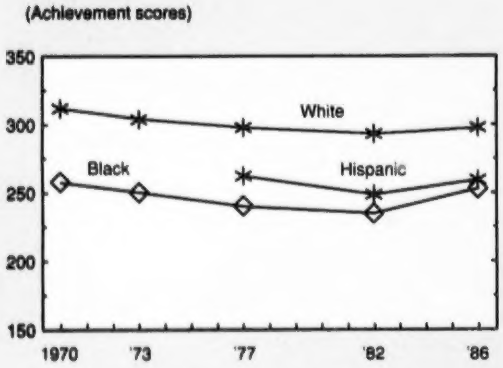
These performance levels can be characterized as the interaction between knowing about science and gaining the ability to perform scientific experiments and using scientific information to infer relationships and draw conclusions.[12] The science specialists who constructed the NAEP items established the level at which students have the ability to analyze scientific procedures and data as characterizing "... the sort of scientific literacy one might expect to be universally held by members of society."[13]

Figure 1-3.
Trends in average science proficiency for age 13, by race/ethnicity: 1970-86



See appendix table 1-1. *Science & Engineering Indicators—1989*

Figure 1-4.
Trends in average science proficiency for age 17, by race/ethnicity: 1970-86



See appendix table 1-1. *Science & Engineering Indicators—1989*

Results of the NAEP analyses of the five levels of student proficiency show that, although recent progress has been made in average student proficiency, most of this has occurred at the lower end of the scale in the areas of basic knowledge and elementary interpretation of scientific information.[14] (See appendix tables 1-3, 1-4, and 1-5.) Approximately 10 percent of junior high school students and only about 40 percent of high school students can be considered moderately versed in science (i.e., able to analyze scientific procedures and data). Only 7.5 percent of the 17-year-olds demonstrated the ability to integrate specialized scientific information. (See text table 1-1.)

By 1986, nearly all students in all three age groups attained a level of scientific knowledge that might be gained from everyday experiences, including elementary

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[12] The 1986 NAEP science assessment did not include "hands-on" exercises designed to measure students' ability to "do" science in terms of their ability to use laboratory equipment and apply higher-order thinking skills in experimental situations. The importance of the key types of hands-on exercises was indicated by a recent report of the National Academy of Sciences, which posited that multiple-choice tests are not adequate for assessing conceptual knowledge, most process skills, and the higher-order thinking that scientists, mathematicians, and educators consider most important. Among the types of tests this report advocated were exercises that employ free-response techniques—not only paper and pencil problems but also hands-on science experiments and computer simulations. See Murnane and Raizen (1988), p. 63. Accordingly, the NAEP staff has launched a pilot study of innovative hands-on techniques and exercises to simulate laboratory processes and analytical and interpretative skills needed for problem solving and reasoning of the type used in scientific experiments. See NAEP (1987).

[13] NAEP (1987), p. 48.

[14] See NAEP (1988a), pp. 40-50, for examples of assessment items that typify each level of performance.

Text table 1-1. Percentage of students at or above the five proficiency levels in science, by age: 1977-86

Proficiency level	Age	1977	1982	1986
		Percent		
Knows everyday science facts	9	93.6	95.0	96.3
	13	98.6	99.6	99.8
	17	99.8	99.7	99.9
Understands simple scientific principles	9	67.9	70.4	71.4
	13	85.9	89.6	91.8
	17	97.2	95.8	96.7
Applies basic scientific evidence	9	26.2	24.8	27.6
	13	49.2	51.5	53.4
	17	81.8	76.8	80.8
Analyzes scientific procedures and data	9	3.5	2.2	3.4
	13	10.9	9.4	9.4
	17	41.7	37.5	41.4
Integrates specialized scientific information	9	0.0	0.1	0.1
	13	0.7	0.4	0.2
	17	8.5	7.2	7.5

Note: See appendix table 1-2 for definitions of proficiency levels.

See appendix tables 1-1, 1-2, 1-3, 1-4, and 1-5.

Science & Engineering Indicators—1989

facts about the characteristics of animals and the operation of familiar mechanical devices. Also, a significantly greater proportion of both 9- and 13-year-olds demonstrated knowledge of simple scientific principles in 1986 than in 1977. In 1977, 68 percent of the 9-year-olds and 86 percent of the 13-year-olds showed the ability to understand simple scientific principles. Nearly all of the 17-year-olds attained this level in the three latest assessments.

It is of great concern that only about 15 percent of the black and Hispanic 17-year-old students assessed in 1986 demonstrated the ability to analyze scientific procedures and data, compared to nearly half the white students at this age. (See appendix table 1-5.) Of similar concern is that at age 17, roughly half the males, but only a third of the females, were able to analyze scientific procedures and data.

Based on these analyses of levels of proficiency, especially the fact that less than half of all high school students were able to analyze scientific procedures and data, the science educators who assisted in preparing the report concluded that:

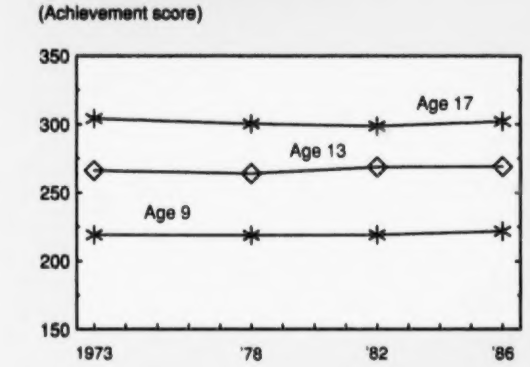
> "In limiting opportunities for true science learning, our Nation is producing a generation of students who lack the intellectual skills necessary to assess the validity of evidence or the logic of arguments, and who are misinformed about the nature of scientific endeavors. The NAEP data support a growing body of literature urging fundamental reforms in science education—reforms in which students learn to use the tools of science to better understand the world that surrounds them."[15]

Mathematics Achievement

Findings from the 1986 mathematics NAEP assessment were similar to those from the science study. Recent mathematics performance has improved somewhat, especially for students at ages 9 and 17. (See appendix table 1-6.) Since 1978, blacks and Hispanics at ages 9, 13, and 17 made appreciable gains. All of these performance improvements, however, have been confined primarily to the lower-level skills. The highest level of performance attained by any substantial proportion of students in 1986 reflects only moderately complex skills and understandings. Most students, even at age 17, do not possess the breadth and depth of mathematics proficiency needed for advanced study in secondary school mathematics.[16]

In the 14-year span covered by NAEP's four mathematics assessments, performance of 9-year-olds was stable between 1973 and 1982 and improved slightly between 1982 and 1986. (See figure 1-5, figure O-13 in Overview, and appendix table 1-6.) Thirteen-year-olds showed some improvement between 1978 and 1986. For 17-year-olds, performance declined slightly from 1973 to 1982, but showed an upturn between 1982 and 1986.

Figure 1-5.
National trends in average mathematics achievement: 1978-86



See appendix table 1-6. *Science & Engineering Indicators—1989*

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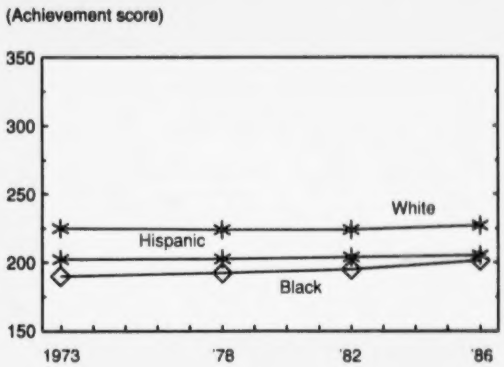
[15] NAEP (1987), p. 17.

[16] NAEP (1988b).

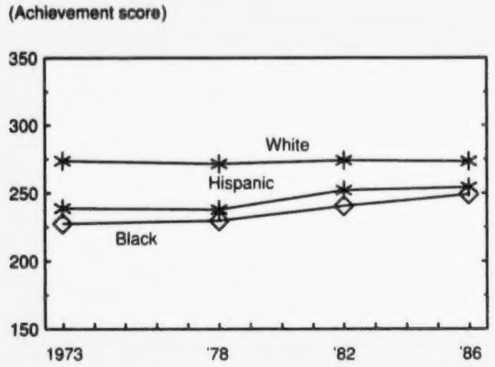
Achievement by Minorities. At ages 9 and 13, black students have shown steady improvement across the 13-year period from 1973 to 1986; these improvements were most notable from 1978 to 1982 and again from 1982 to 1986. (See figures 1-6, 1-7, and 1-8.) At age 17, black students showed relatively consistent performance between 1973 and 1978, before improving between 1978 and 1986. At age 9, Hispanic students improved slightly with each assessment. At the older ages, Hispanic students showed recent improvements, with the performance of 13-year-olds improving primarily between 1978 and 1982, and that of 17-year-olds improving primarily between 1982 and 1986. Because performance of white students remained at approximately the same level in 1986 as in 1973, while the black and Hispanic scores gained (particularly at age 13), the performance gap between these groups narrowed appreciably.

Figure 1-6.
Trends in average math achievement for age 9, by race/ethnicity: 1973-86



See appendix table 1-6. *Science & Engineering Indicators—1989*

Figure 1-7.
Trends in average math achievement for age 13, by race/ethnicity: 1973-86



See appendix table 1-6. *Science & Engineering Indicators—1989*

Factors Behind Changes in Test Scores

A study by the Educational Testing Service (ETS) examined changes in the academic achievement of high school seniors (as measured by various test results, including the NAEP assessments) between 1972 and 1980 and examined the school and student factors related to these changes. (See Rock, et al., 1985.) The findings show that significant shifts in the characteristics of high schools and student behavior were related to test scores. Changes during the period studied at the school and student levels that seem to be most closely associated with lower test scores were:

- A greater likelihood of being in the general or vocational curriculum rather than the academic curriculum;
- A drop in the frequency with which students report taking "traditional" college preparation core courses such as foreign languages, science, and/or courses requiring laboratory work;
- A decrease in the amount of homework done; and
- An increasing dissatisfaction among students with the lack of emphasis on academics in the schools.

This dissatisfaction—shared by students of all socioeconomic statuses (SES) and racial/ethnic groups—was the overall major factor associated with lower test scores. The impact of this shift in emphasis fell primarily on white and upper class students. On the other hand, Federal and state programs designed to strengthen skills in mathematics among low SES blacks appear to have contributed to the test score increase in mathematics among this group.

Achievement by Females. Gender differences in mathematics performance were smallest at age 9 and greatest at age 17; in 1986, 17-year-old males scored 5 points higher than females on the proficiency scale. (See appendix table 1-6.) At age 9, females scored higher than males until 1986, when the scores were identical, due to a greater improvement in male scores than female scores between 1982 and 1986. Females at age 13 scored higher than males in the first two assessments; the reverse was true in 1982 and 1986, although both genders showed improved proficiency in 1986 compared with 1973.

Levels of Student Proficiency in Mathematics

As in the science NAEP assessment, five levels of mathematics proficiency were established, in this case by a team of mathematics educators.[17]

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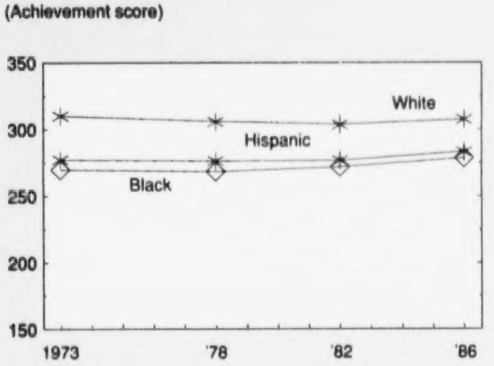
[17] See footnote 9 and appendix table 1-7.

Figure 1-8.
Trends in average math achievement for age 17, by race/ethnicity: 1973-86



See appendix table 1-6. *Science & Engineering Indicators—1989*

Text table 1-2. Percentage of students at or above the five proficiency levels in mathematics, by age: 1978-86

Proficiency level	Age	Assessment year 1978	 1982	 1986
		Percent		
Simple arithmetic facts	9	96.5	97.2	97.8
	13	99.8	99.9	100.0
	17	100.0	100.0	100.0
Beginning skills and understanding	9	70.3	71.5	73.9
	13	94.5	97.6	98.5
	17	99.8	99.9	99.9
Basic operations and beginning problem solving ..	9	19.4	18.7	20.8
	13	64.9	71.6	73.1
	17	92.1	92.9	96.0
Moderately complex procedures and reasoning ..	9	0.8	0.6	0.6
	13	17.9	17.8	15.9
	17	51.4	48.3	51.1
Multi-step problem solving and algebra	9	0.0	0.0	0.0
	13	0.9	0.5	0.4
	17	7.4	5.4	6.4

Note: See appendix table 1-7 for definitions of proficiency levels.

See appendix tables 1-6, 1-7, 1-8, 1-9, and 1-10.

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- Simple arithmetic facts.
- Beginning skills and understanding.
- Basic operations and beginning problem solving.
- Moderately complex procedures and reasoning.
- Multi-step problem solving and algebra.

The performance level associated with "moderately complex procedures and reasoning" represents the level of attainment recommended by the National Science Board (NSB) that all secondary students should achieve, including a variety of mathematical outcomes such as an understanding of the logic behind algebraic manipulations, a knowledge of two- and three-dimensional figures and their properties, and some more advanced objectives.[18]

In 1986, only about half of the 17-year-old age group was able to attain the proficiency level recommended by the NSB. (See text table 1-2.) Moreover, only a small proportion of 17-year-olds (6 percent) showed the ability to do multi-step problem solving and algebra in the 1986 assessment. The percentage of students achieving at this level has remained essentially constant since 1978. This means that few students have, by their last years of high school, mastered the fundamentals needed to perform more advanced mathematical operations.

On a more positive note, in 1986—as in past assessments—virtually all students in all three age groups were able to perform elementary addition and subtraction. There was also some improvement in performing beginning skills and understanding: more 13-year-olds could solve the test items designed to measure basic operations and beginning problem solving in 1986 (73 percent) than in 1978 (65 percent). Most of this gain occurred between 1978 and 1982. (See appendix tables 1-8, 1-9, and 1-10.)

Among the conclusions reached by the authors of the mathematics assessment was the following:

> "Too many students leave high school without the mathematical understanding that will allow them to participate fully as workers and citizens in contemporary society. As these young people enter universities and businesses, American college faculty and employers must anticipate additional burdens. As long as the supply of adequately prepared precollegiate students remains substandard, it will be difficult for these institutions to assume the dual responsibility of remedial and specialized training; and without highly trained personnel, the United States risks forfeiting its competitive edge in world and domestic markets."[19]

International Assessments of Science and Mathematics Achievement

In recent years, two large-scale international assessments of science and/or mathematics have been conducted. The first was performed in 1988 by the International

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[18] NSB (1983), pp. 94-96.

[19] NAEP (1988b), p. 9.

Assessment of Educational Progress (IAEP); it tested 13-year-old students in mathematics and science in five countries and four Canadian provinces.[20] The second assessment, by the International Association for the Evaluation of Educational Achievement (IEA), covered science in 24 countries or systems. The IEA study included students at three levels: age 10, typically grades 4 or 5; 14-year-olds, or grades 8 and 9—the point in secondary school when education in most systems is still full-time and compulsory—and students who were enrolled in science in the terminal year of high school.[21] In the U.S., most students in the 12th grade who are still enrolled in science are taking physics or a second year course in some science.

Both of these assessments point to the same conclusion: U.S. students perform poorly in science and/or mathematics compared with most of their counterparts around the world.

International Assessment of Educational Progress. In the IAEP mathematics assessment, the U.S. ranked last among the five countries and four Canadian provinces.[22] (See figure 1-9 and appendix table 1-11.) Thirteen-year-old students in South Korea had the highest proficiency levels in mathematics—well above the mean—while the other 11 populations clustered themselves into three lower-performing groups.

In the 1988 IAEP science assessment, the U.S. was also among the lowest scoring populations, which included Ireland, French-speaking Ontario, and French-speaking New Brunswick. (See figure 1-10 and appendix table 1-12.) The students of British Columbia and South Korea were by far the highest scorers. The performances of about half the countries were clustered near the mean for all participants.

To make informed judgments about the adequacy of student skills in science and math, the IAEP international tests were scaled at five points similar to the U.S. NAEP science and math assessments.[23] (See appendix tables 1-13 and 1-14.) In mathematics, the results show that South Korean students were much more proficient in solving

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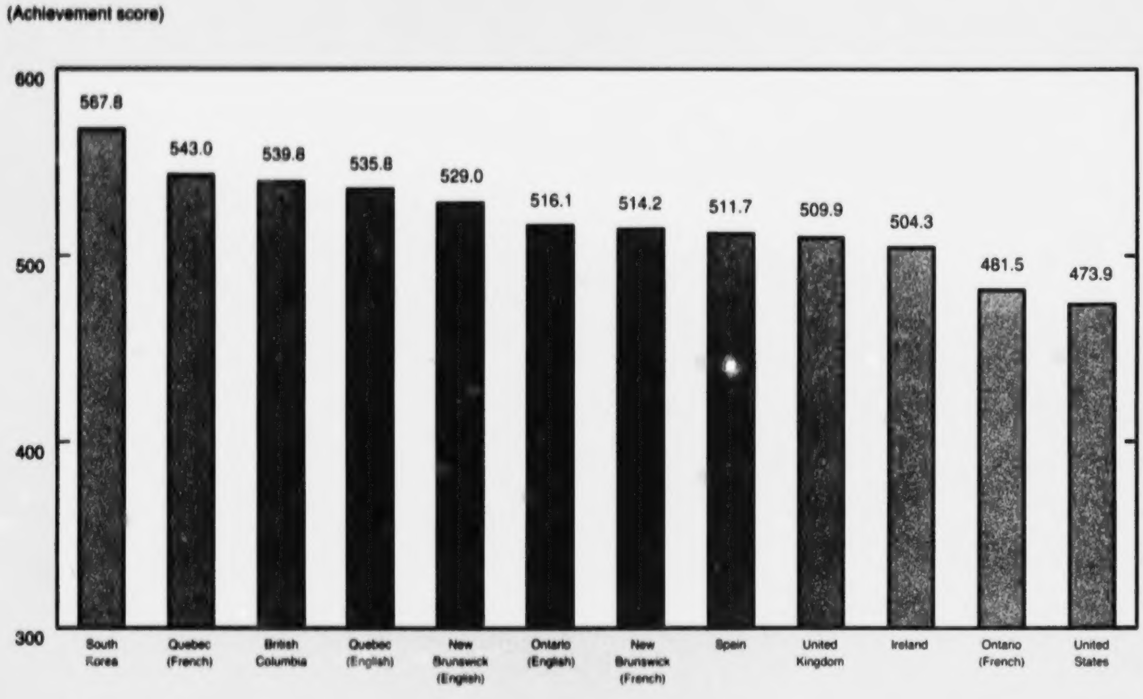
[20] In the IAEP study, test items were taken from the 1986 NAEP assessments of science and mathematics.

[21] At the time of preparation of this report, data were available for 15 countries at age 10, 16 countries at age 14, and 14 countries at the terminal year of high school.

[22] Lapointe, Mead, and Phillips (1989).

[23] Ibid.—see the Procedural Appendix for a discussion of statistical methodology used to scale the various levels of student proficiency. Also see footnote 9.

Figure 1-9.
Average math achievement for age 13, by country: 1988



See appendix table 1-11.

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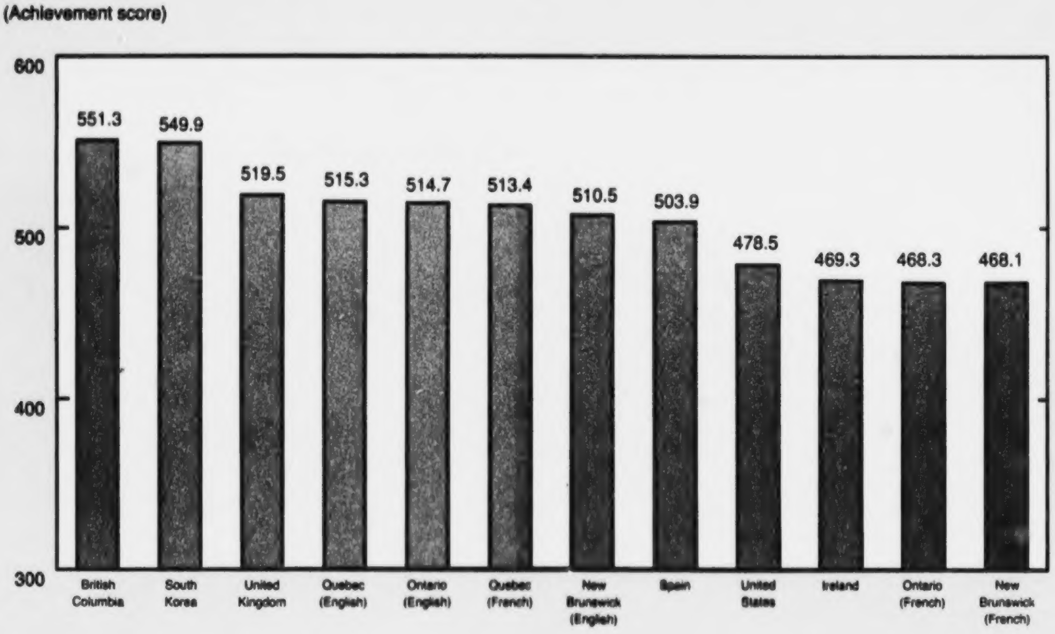
Figure 1-10.
Average science achievement for age 13, by country: 1988



See appendix table 1-12.

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complex problems than students in most other countries, including the United States. (See appendix table 1-15.) More than three-quarters of the 13-year-old South Korean students could use intermediate mathematical skills to solve two-step problems, compared with only 40 percent of the U.S. students. In terms of understanding measurement and geometry concepts and applying problem solving to more complex mathematical problems, 40 percent of the South Korean, compared with only 9 percent of the U.S., students were successful.

In science, over 70 percent of the 13-year-olds in both British Columbia and South Korea demonstrated the ability to use scientific principles and analyze scientific data, compared with only 42 percent of the American students. (See appendix table 1-16.) Over 30 percent of the students in British Columbia and Korea were successful in solving problems designed to measure the understanding and application of scientific knowledge and principles, compared with less than 12 percent of the students in U.S.

IEA International Science Assessment.[24] In the IEA international science assessment, students in Japan and South Korea (each with average scores of 15.4 out of a possible 24 correct answers to test items) were the top performers among 10-year-olds. U.S. students, along with those from a number of other countries, were in the middle with a mean score of 13.2. The 10-year-old students in the United Kingdom and Hong Kong were among the lowest scorers in the country rankings.

By the intermediate level of schooling, Hungarian, Japanese, and Dutch 14-year-olds demonstrated the highest achievement, correctly answering roughly 20 to 22 of 30 items. U.S. 14-year-old students ranked third to last with an average of about 17 items correct.

At the terminal year of high school, among students who took biology, chemistry, or physics, students in Hong Kong and the United Kingdom were among the highest scorers, with the U.S. students ranking last in biology, third from last in chemistry, and fifth from last in physics. (See figures 1-11, 1-12, and 1-13; and appendix tables 1-17, 1-18, and 1-19.)

Thus, U.S. 10-year-old students in science ranked in the middle of the countries, lost ground by age 14, and scored at or near the bottom by the 12th grade. The opposite pattern is observed in Hong Kong and the United Kingdom, where 10-year-old students score relatively low, but—by the terminal year of high school—move up in the international rankings.

There are several possible explanations for this

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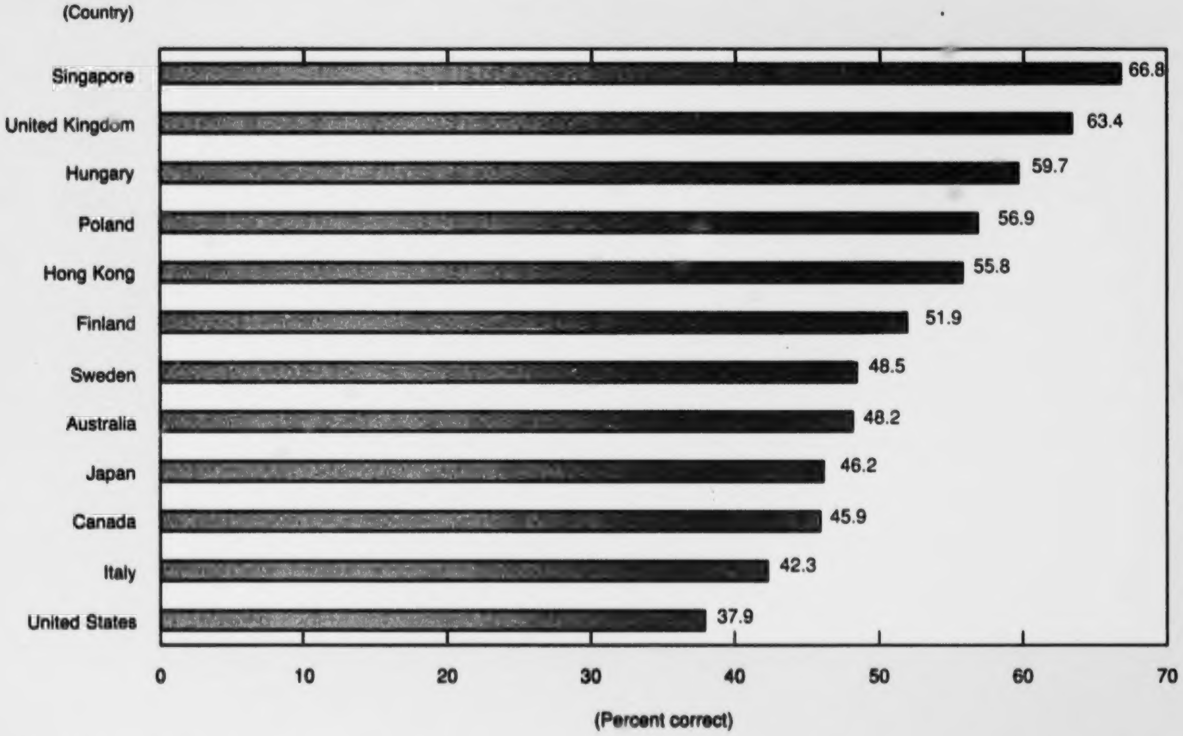
[24] In the IEA science study, most of the countries conducted the assessment in 1983. In the U.S., two assessments were conducted, one in 1983 and another in 1986, but the 1983 survey was marked by extremely low response rates and, as a result, these data are not shown here. See International Association for the Evaluation of Educational Achievement (1988), p. 26.

Figure 1-11.
Mean scores on biology test: among students taking biology in final year of high school, by country



Note: Data are for 1986 in U.S. and 1983 for other countries.
See appendix table 1-17.

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phenomenon. In some countries, notably Hong Kong and the United Kingdom, secondary school students who are skilled in science are provided with the opportunity to study the science curriculum much more intensively than in the United States. Also, in some countries, high achievement is associated with high student attrition rates. Students who do not achieve well drop out early. In Thailand, for example, where scores of 14-year-old students equaled those of U.S. students in the IEA study, only 32 percent of this age group is in school, as opposed to 99 percent of U.S. students. Thus, in-school 14-year-olds in Thailand are a select group of students. On the other hand, however, Japan—a country typically among the highest scoring ones in international assessments of science and mathematics—has a higher student retention rate than does the United States.

Another possible explanation of why the U.S. scores relatively low in international assessments of science and mathematics lies in the type of curriculum studied. Other studies have shown that the science curriculum in the United States is different from that in most other countries. In the United States, most public schools teach one science subject for one academic year and then move on to another discipline the following year; in contrast, the preferred approach in certain other countries is the parallel teaching of an array of disciplines over a period of years.[25] Other speculative explanations include family and community expectations and support.

Computer Competency

Overall, the computer competency assessment found that most students have used computers and have some familiarity with them, but that their competency is generally low and largely restricted to relatively simple computer applications such as word processing. Further, computers are seldom used in subject areas such as mathematics or science, but rather are largely confined to classes about computing and the use of computers.[26]

More than 60 percent of 11th graders correctly identified the word processing functions of "search and replace," "insertion," and "movement of text." (See appendix table 1-20.) At all three grade levels tested, however, students

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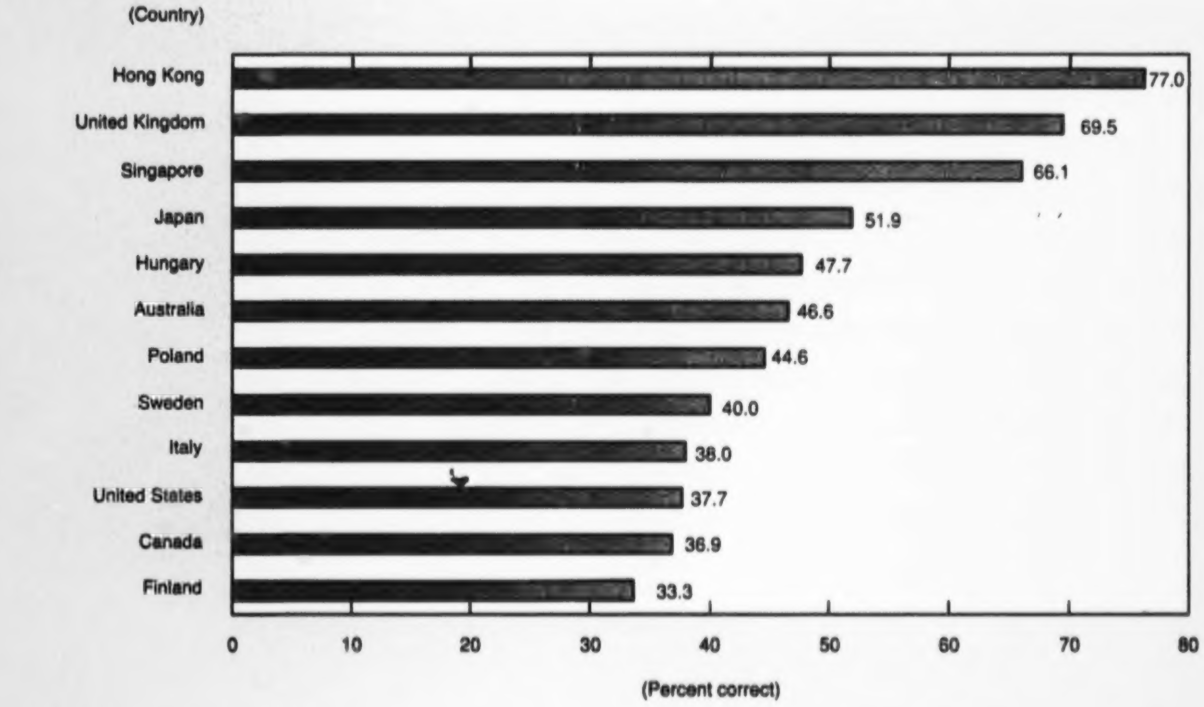
[25] Klein and Rutherford (1985).

[26] NAEP (1988c).

Figure 1-12.
Mean scores on chemistry test: among students taking chemistry in final year of high school, by country



Note: Data are for 1986 in U.S. and 1983 in other countries.
See appendix table 1-18.

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did not have a clear grasp of graphics functions or the structure and functions of data bases. Only about 10 percent of 7th and 11th graders practiced such applications as often as once a week. About two-thirds of these students had never written computer programs.

White students averaged between 5 and 8 points higher on the computer assessment than did their black and Hispanic counterparts. White students also have a definite advantage over blacks and Hispanics in access to computers at home. Male students have slightly higher computer competency than females, although differences in experience and instruction were small. Families of boys, however, were more likely to own computers: among 11th graders, 35 percent of boys had computers at home, compared with 25 percent of girls.

More than half of grade 3 students have used computers in mathematics classes. But when 7th and 11th grade students were asked how often they used computers in various subject areas, it became clear that computers are primarily confined to the school computer studies curriculum. (See appendix table 1-21.) High percentages of students never use a computer to practice mathematics, science, reading, or other skills from traditional subjects. (See text table 1-3.) Among those who used a computer to practice subject matter skills, only about 5 percent to 10 percent did so more than once a week.

Text table 1-3. Computer use in subject areas, by grade level: 1986

Have you used a computer in any of the following classes?	Grade 3	Grade 7	Grade 11
	Percent		
Mathematics	53.0	39.4	29.1
Reading/English	25.0	23.9	16.9
Science	12.8	11.6	15.4
Social studies	11.7	10.2	4.6
Art	21.6	10.2	4.6
Music	16.9	7.0	3.9

SOURCE: NAEP (1988c).

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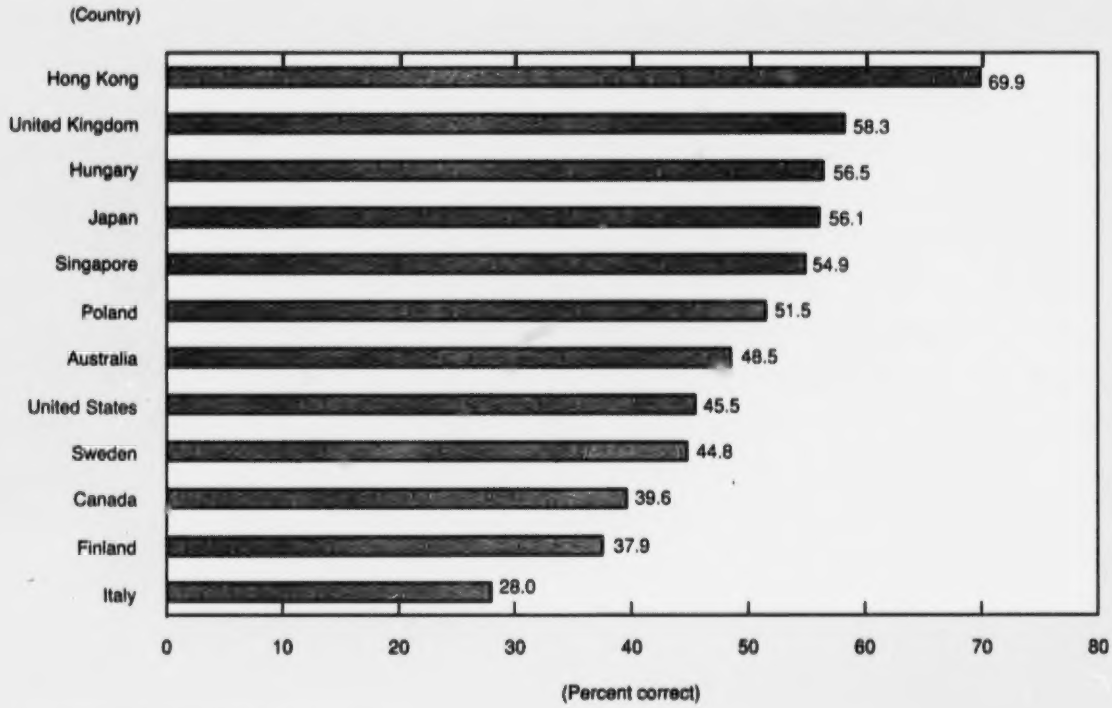
Figure 1-13.
Mean scores on physics test: among students taking physics in the final year of high school, by country



Note: Data are for 1986 in U.S. and for 1983 in other countries.
See appendix table 1-19.

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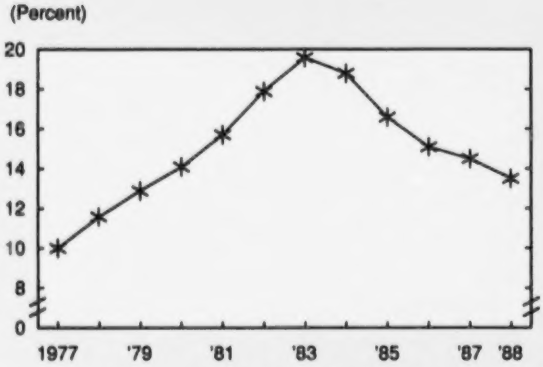
Science and Engineering Interests of College-Bound Seniors

An important indicator of the potential supply of scientists and engineers is the proportion of high school seniors who intend to major in S/E fields in college. Based on the plans of college-bound seniors who take the Scholastic Aptitude Test (SAT), there has been a decline in the proportion of students intending to major in the more quantitative sciences—math and statistics, the physical sciences, engineering, and computer science. (See figure 1-14 and appendix table 1-22.)[27] During the 12-year period from 1977 to 1988, the proportion of college-bound high school seniors who intended to major in these S/E fields doubled, peaking at about 20 percent in 1983, and then gradually declining to about 13 percent in 1988.

Engineering is the most popular of the four quantitative fields; it has held its own since the early 1980s with between 9 percent and 10 percent of college-bound seniors expressing an interest in majoring in it. This represents an increase over the 6 percent of students planning an engineering major in 1977. Interest in computer science dropped from a high of about 7 percent in the early 1980s

Figure 1-14.
Percentage of college-bound seniors intending to major in science and engineering: 1977-88



See appendix table 1-22.

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[27] Grandy (1989); and ETS (1989).

to less than 3 percent in 1988. Interest in both the physical sciences and math and statistics remained low throughout the 12-year period and has been declining. By 1988, less than 1 percent of the college-bound seniors planned to major in each of these fields.

In 1988, 24 percent of the black males, and 21 percent of white males, intended to major in a quantitative science. Only 11 percent of black females and 5 percent of white females expressed an interest in majoring in these fields. Regardless of race, males were more likely to be interested in the applied engineering subfields than were females.

Academic Persistence of High-Ability Minority Students

Are minority students who test high in ability and express an interest in becoming scientists and engineers more or less likely than whites to persist in preparing for these fields? How do those who persist differ from those who don't? To address these issues, a recent study conducted by the Educational Testing Service sampled 5,000 minority high school seniors who (1) scored 550 or above in mathematics on the SAT, and (2) said they planned to major in math, science, or engineering.

By the spring of 1987 (2 years after taking the SAT), 61 percent of the total sample had enrolled in college and were actually majoring in an S/E field or intended to do so.[28] This proportion greatly exceeds the comparable percentage for the general population of minority students. The persistence rate of high-ability minority students was about twice that of their counterparts in the general population. The comparable persistence rate for high-ability white students was 55 percent.

Those who persisted were different from those who did not in several important aspects. The persisters were much more likely to participate in high school math and science courses and related extracurricular activities. More than half of the persisters had taken high school honors courses in science and mathematics, and two-fifths had taken Advanced Placement (AP) mathematics courses. (See appendix table 1-23.) In this regard, a recent study using High School and Beyond data shows that senior high schools serving predominately poor students typically offer fewer AP courses.[29] Almost two-thirds of high socioeconomic status schools offer AP courses, but less than one-fifth of schools in low-SES communities offer them. Science and math clubs, college-based minority science and engineering recruitment and enrichment programs, and science fair/independent research projects also seem to have been influential in their persistence in science and mathematics studies.

OPPORTUNITIES TO LEARN SCIENCE AND MATHEMATICS

As previously noted (see p. 21), a recent National Research Council report on precollege science and mathematics education recommended that (1) *course enrollments* in secondary school and (2) *instructional time* in the elementary and middle schools be used as key indicators in an integrated system of information about science and mathematics learning. Accordingly, this section deals with these indicators.

Course Enrollments in Secondary Schools[30]

A recent study for the U.S. Department of Education found that long-term patterns of high school course offerings have shifted, particularly in the "general" track.[31] For one thing, the proportion of students in this track dropped from 35 percent in 1982 to 17 percent in 1987; nearly all of this change reflected movement into a more rigorous academic curriculum. As a result, students in 1987 took an average of one semester more of mathematics than they did in 1982, and enrollments in advanced math classes (geometry, second-year algebra, trigonometry, and calculus) were up by about a third. (See appendix table 1-24.) The number of students in pre-calculus had more than doubled, while enrollment in remedial mathematics was down by a third since 1982.

Course-taking in science was also up over the 6-year period. (See appendix table 1-25.) While only 75 percent of 1982 high school graduates had taken a whole year of biology, 90 percent had done so by 1987. The number of students taking a year of chemistry increased from 31 percent to 45 percent. Similarly, the average percentage of graduates taking a full year of physics increased from 14 percent to 20 percent.

Proportionally, there were greater increases in course-taking in science, mathematics, foreign languages, and computer science than in the other academic subjects, reflecting the emphasis in state reform movements on these areas. (See figure 1-15 and appendix table 1-27.) For example, the average high school graduate took 2.2 credits of science in 1982, compared with 2.6 credits in 1987. More time for core curriculum subjects such as science and mathematics was accompanied by relatively small decreases in vocational education programs. In addition,

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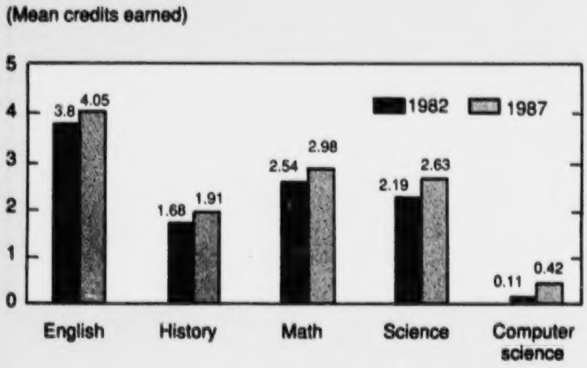
[28] Hilton, et al., (1989), p. 152.

[29] Eckstrom, Goertz, and Rock (1988), p. 50.

[30] An apparent inconsistency is that while student course-taking in secondary math and science has been increasing in recent years, overall student achievement in these subjects has remained relatively static. In this regard, it should be noted that increases in secondary science and mathematics course-taking, as well as the recent increases in some student assessment scores, may portend improvements for the future. Student learning depends on many things besides time spent on a subject. However, the educational reform movements implemented by state and local agencies in the 1980s cannot be expected to have immediate impacts and their full effects may not be seen for some time. In addition, student learning is not only a function of the quantity of time spent on a subject, but also the quality of the curriculum, teacher effectiveness, student interest in particular subjects, availability of adequate laboratories and facilities, and family and community expectations.

[31] In this study, transcripts of 1987 high school graduates were compared with transcripts of 1982 graduates to describe changes in course-taking across this 6-year period. The analyses were based on approximately 15,000 transcripts of 1987 graduates obtained as part of the 1987 High School Transcript Study and 12,000 transcripts of 1982 graduates who participated in the High School and Beyond project. See Westat, Inc., (1988).

Figure 1-15.
Mean number of credits earned by high school graduates: 1982 and 1987



See appendix table 1-27. *Science & Engineering Indicators—1989*

some high schools appear to be lengthening the school day, shortening class periods, and placing less emphasis on noncredit courses such as study hall, gym, and driver's education.[32]

There was a substantial increase in the proportion of high school graduates taking Advanced Placement courses in mathematics and physics. For example, the proportion of graduates taking AP/honors calculus courses increased from 1.5 percent in 1982 to 3.4 percent in 1987; AP/honors physics increased from 1.1 percent to 1.8 percent. Simultaneously, the proportion of students in AP/honors biology decreased from 6.6 percent to 3.0 percent; chemistry essentially held its own (going from 2.9 percent to 3.1 percent). As a result, 66,227 secondary students took the AP mathematics exam in 1988 compared with 31,918 students in 1982. Similar numbers for the AP physics exam were 15,266 in 1988 and 6,804 in 1982.[33]

Course-Taking Trends Among Minorities. There were notable increases in the average number of credit hours taken in mathematics among all racial and ethnic groups. (See figure 1-16 and appendix table 1-26.) The largest increases were shown for Asians, who also took the greatest number of credits in mathematics in both 1982 and 1987.

Course-Taking Trends for Females. The rate of growth for course-taking by female high school students in mathematics was considerably higher than for males, but the average number of credits taken remained higher for males than for females. Females took an average of 2.93 credits in mathematics in 1987, up from 2.46 credits in 1982. Comparable figures for males were 3.04 credits in 1987 and 2.61 credits in mathematics in 1982. The average number of credits taken in science by males and females went up equally—from 2.25 to 2.69 (males), and from 2.13 to 2.57 (females). (See appendix table 1-27.)

Racial, Ethnic, and Socioeconomic Aspects of Opportunities to Learn Science and Math in Secondary Schools

Despite recent gains, the average science and math achievement of 13- and 17-year-old black and Hispanic students remains several years behind that of their white peers. One possible explanation of the relatively poor performance of minority students is that they have fewer opportunities to learn these subjects and that the opportunities they do have are of less quality than those available to white students. To assess this situation with respect to science and mathematics, a recent study by the RAND Corporation attempted to provide a comprehensive set of analyses to determine if and how disparities in school opportunities disadvantage poor and minority students.

Based on preliminary analyses of data from the 1986 National Survey of Science and Mathematics Education (Weiss, 1987), the RAND study showed that a pattern of uneven distribution does exist. For example, based on teachers' reports of their perceptions of the general science and math ability of students enrolled in their classes, students who attend schools with high minority enrollments are far more likely than other students to be enrolled in low-ability science and math classes and far less likely to be in high-ability classes. (See Oakes, et al., n.d.) Student enrollment in classes that teachers perceive to be of "high ability" was only 16 percent in schools where nonwhites comprise more than 90 percent of the school population, while 43 percent were enrolled in "high-ability" classes in schools where white students made up more than 90 percent of the total enrollment. (See appendix table 1-28.)

The same patterns are evident when student ability in science and math is compared with socioeconomic status, as measured by the percentage of students with parents who are unemployed or on welfare and the percentage of students with parents in professional or managerial occupations. As secondary schools become more affluent, they have fewer classes at low-ability levels and more at high-ability levels.

The study authors concluded that poor and minority students are more likely to find themselves in low-ability classes and in courses focused on "general" math and science content. Consequently, students have less access to the topics and curricular objectives that could prepare them for successful participation in academic courses in math and science. On the other hand, whites and students from more affluent families are more likely to be identified as able learners, placed in academic classes, and have greater opportunities to take the critical courses (such as advanced mathematics and calculus) necessary for successful science and math achievement in higher education. In this regard, a recent study comparing course-taking patterns between 1982 and 1987 found that while black high school graduates in 1987 were more likely than in 1982 to study all subjects except calculus, they continued to lag substantially behind white graduates in advanced math courses. (See ETS, 1989, pp. 4-5.) The course-taking patterns for Hispanics generally resembled those of blacks.

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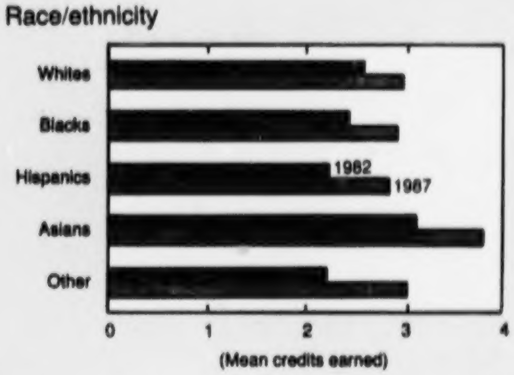
[32] Judy McNeil Thorne, the Westat, Inc., project director of 1987 High School Transcript Study (personal communication).

[33] The College Board (1988).

Figure 1-16.
Mean number of credits in mathematics earned by high school graduates, by race/ethnicity: 1982 and 1987



See appendix table 1-26. *Science & Engineering Indicators—1989*

Science and Mathematics Instruction in Elementary and Middle Schools[34]

The amount of time spent teaching science and mathematics in elementary schools remained substantially the same between 1977 and 1986. (See appendix table 1-29.) An average of only 18 minutes per day was spent on teaching science in 1986 at grades K-3, compared with around 29 minutes in grades 4-6. Substantially more time was devoted to mathematics at both grade levels. At grades K-3, an average of 43 minutes per day was spent on mathematics in 1986, and around 52 minutes in grades 4-6.

On average, in both 1977 and 1986, elementary school teachers reported spending the greatest amount of classroom time in teaching reading; this was followed by time for mathematics, social studies, and science. (See figure 1-17.)

More specifically, when teachers of third grade students were asked how much time they spent teaching science compared with carrying out other classroom activities during a typical week, half reported spending only 1 to 2 hours each week providing science instruction. About 20 percent of the teachers reported spending less than 1 hour per week teaching science. Only 5 percent reported spending 5 or more hours per week on science. (See appendix table 1-30.)

At grade 7, the amount of time spent teaching science still appears to be relatively low, with approximately half of the seventh grade teachers reporting that they devoted 3 hours or less to science instruction each week. Only 14 percent of the teachers reported that they spent 5 hours or more each week teaching science.

Classroom Activities

When teachers were asked as part of the 1986 National Survey to indicate what took place during their most recent lessons in science and mathematics classrooms, they said that most science lessons included lecture and discussion rather than hands-on activities. Use of hands-on activities was more common in elementary school (51 percent of lessons) than in secondary school (43 percent in grades 7-9 and 39 percent in grades 10-12).[35]

Approximately two-thirds of elementary science teachers, and more than three-quarters of secondary teachers, indicated that they believe that laboratory-based activities are more effective than nonlaboratory classroom practices (including lectures). Fewer than 5 percent of the sampled teachers in each group agreed with the statement "Hands-on science experiments are not worth the time and expense." Despite this attitude, experiments conducted in laboratories constitute less than a quarter of the time spent in science classrooms.

At least part of the reason why hands-on science activities are not more prevalent is because many schools lack access to laboratories. In the 1986 National Survey, 38 percent of all elementary teachers surveyed reported that their classrooms have no science materials or facilities. In the 1986 NAEP assessment, slightly less than half of all secondary teachers reported that they had access to a general-purpose laboratory for use in teaching science. (See text table 1-4.) And only one-fifth of the seventh grade teachers had access to more specialized facilities (i.e., a biology or chemistry laboratory).

Text table 1-4. Teacher access to laboratory facilities, by grade level: 1986

	Grade 7	Grade 11
	Percent responding "yes"	
Do you have access to a general purpose laboratory for your teaching?	46	45
Do you have access to a specialized science laboratory for your teaching?	20	64

SOURCE: NAEP (1988a), p. 96.

Science & Engineering Indicators—1989

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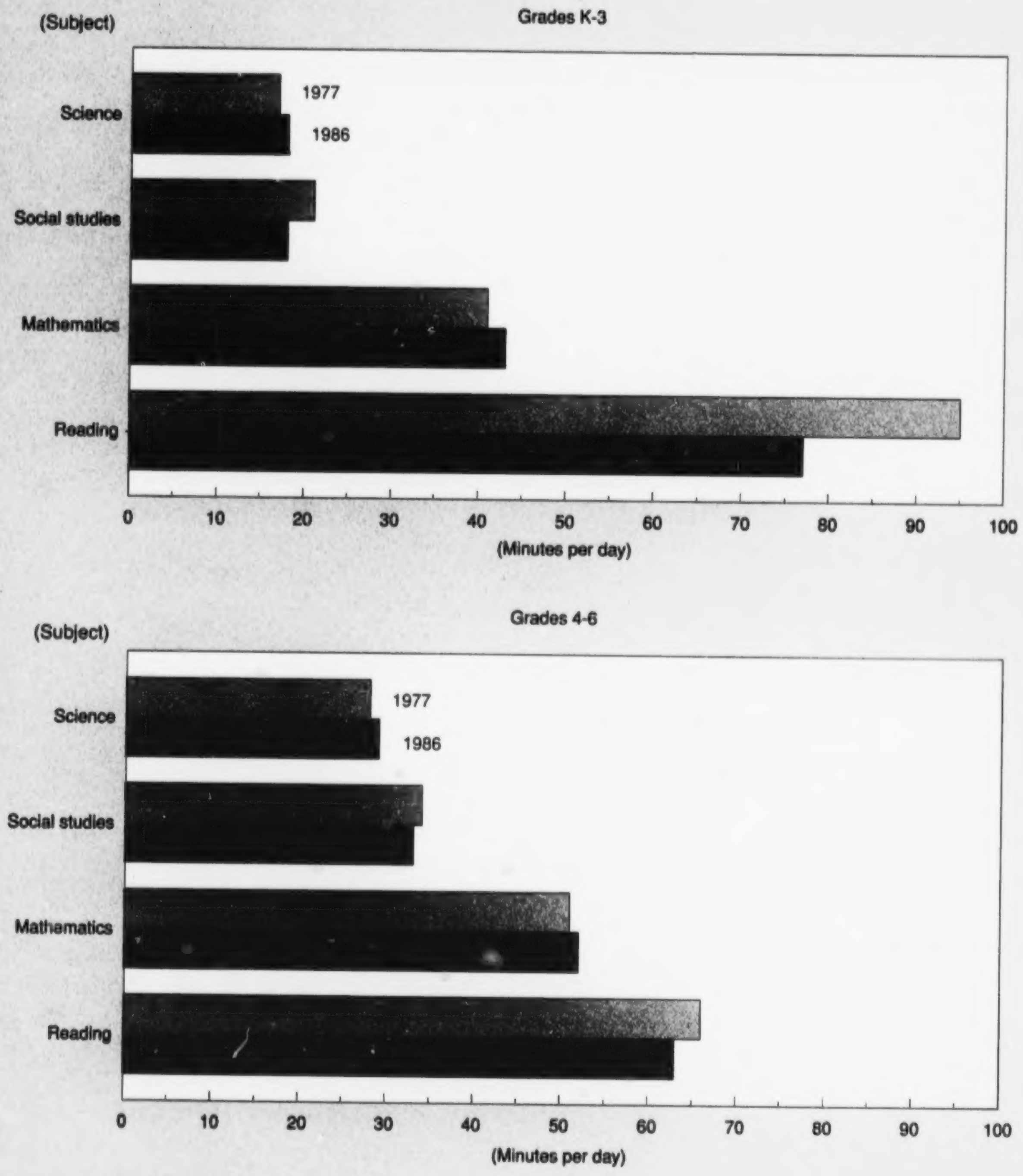
[34] Recent data on student exposure to science instruction in elementary and middle schools are available from two sources: (1) for all grades at each level in 1977 and 1985-86 from the National Survey of Science and Mathematics Education (Weiss, 1987), and (2) for 1986 at ages 9 and 13 (generally grades 3 and 7) from the science and mathematics assessments conducted by the National Assessment of Educational Progress (NAEP, 1988a and 1988b). In the 1986 National Survey, teachers were asked to report the number of minutes spent in their most recent lesson in a particular subject.

[35] Weiss (1987), pp. 47-51.

Figure 1-17.
Average number of minutes per day spent by elementary school teachers in each subject, in self-contained classes, by grade range: 1977 and 1986



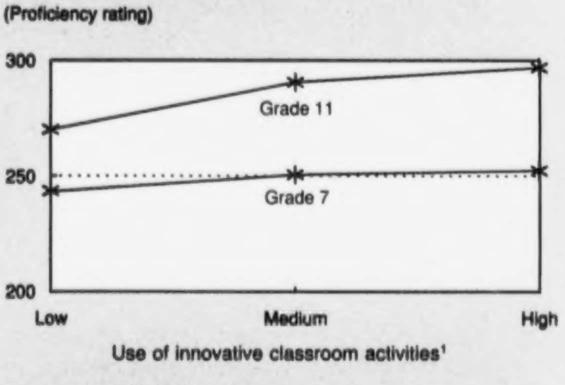
See appendix table 1-29.

Science & Engineering Indicators—1989

Special analyses of the 1986 NAEP data indicate that innovative classroom practices (such as problem solving and conducting experiments in connection with laboratory exercises) are likely to be associated with higher science proficiency. To conduct these analyses, students were asked to report how often they solved problems, conducted experiments alone or with other students, wrote up the results of experiments, read articles on science, and presented oral or written reports. Responses to these questions were ranked as "low," "medium," or "high." Students whose teachers often lectured and seldom engaged the class in experimentation were at the low end of the scale. Those whose teachers used more innovative techniques such as hands-on science experiments and hypothesis testing were ranked at the high end of the scale.

These student-reported types of classroom activities were correlated with actual student achievement scores for the same students. Figure 1-18 shows a positive relationship between science proficiency and innovative instructional activities, even though, as noted above, these practices are relatively rare. The report summarizing the 1986 NAEP data on these questions indicates, however, that it is not possible to determine whether students with greater science proficiency tend to be placed in classes that consist of more innovative curricular activities—or whether these activities yield higher proficiency.[36] The relationship between innovative instructional activities and student proficiency is confounded further by positive correlations between student achievement and a number of other significant factors, including the use of science equipment in the classroom, the ability of the school to instill positive student attitudes toward science, and the beliefs students hold regarding science's applicability in helping remedy human and environmental problems.

Figure 1-18.
Average science proficiency, by types of teaching and instructional activities: 1986



¹For definitions, see this page above.
SOURCE: NAEP, 1988. *Science & Engineering Indicators—1989*

Classroom Science and Mathematics Practices in Other Countries. The IAEP international science assessment found that students in the U.S. were the least involved in laboratory experiments and other types of hands-on activities of any of the six countries in the assessment.

In terms of mathematics instruction, however, detailed analyses of eighth grade data from the more extensive 1981-82 Second International Mathematics Study showed that there is a great deal of similarity in teaching practices in the eighth grade around the world. Slightly more than a third of the teachers in that study reported that the majority of class time in mathematics was taken up with the whole class working together as a group, either listening to the teacher lecture or participating in discussions. Teachers in the participating countries reported spending comparatively little time in small group instruction. In all countries studied, more than 75 percent of the teachers reported spending less than 25 percent of their class time in small groups.[37]

Classroom Activities, as Reported by Students. In the 1986 NAEP assessments of science and mathematics, students were asked to report on their teachers' instructional practices and the kinds of learning activities featured in their science and mathematics classrooms. While most science educators encourage the use of hands-on activities, science instruction continues to be dominated by teacher lectures and the reading of textbooks. In fact, the instructional technique reported most often by students was reading science textbooks: over half the students in grades 3, 7, and 11 stated that they read textbooks daily or weekly. Other learning opportunities appear to be neglected. For example, over half the students in third grade said they never went on field trips with their science classes. Of the students in grade 7:

- Over four-fifths never went on science field trips,
- Over half never wrote up the results of experiments,
- About half reported that they never conducted independent science experiments, and
- Nearly half said they never did oral or written reports for science classes. (See appendix table 1-31.)

Among 11th grade students:

- 90 percent reported that they had never done experiments alone, although approximately half reported that they had performed experiments on a weekly basis with other students;
- Slightly more than half reported never doing oral or written reports; and
- Nearly half reported never having gone on field trips or written up results from science experiments. (See appendix table 1-31.)

Similar results were shown for mathematics teaching, where routine instructional approaches predominate.

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[36] NAEP (1988a), p. 97.

[37] Burstein (in press).

Use of Calculators and Computers in the Classroom

In the 1986 NAEP mathematics assessment, relatively few students reported having access to *calculators* in school. Only 15 percent of all third graders have calculators for use in mathematics classes and only 21 percent of the seventh grade students and 26 percent of the senior high students used them in mathematics classes at school.

Larger numbers of students reported using *computers* for mathematical purposes, e.g., for learning mathematics through computer instruction, solving mathematical problems, or learning computer programming. Studying aspects of mathematics through computerized instruction seems to peak in junior high school: 39 percent of the 13-year-olds reported having computerized mathematics instruction, compared with only 22 percent of the 17-year-olds. At age 17, access to computers more than doubled between 1978 and 1986; however, most of the increases have occurred in connection with initial high school mathematics courses, such as pre-algebra and algebra I (first year).

Amount of Science and Mathematics Homework

Both the 1986 National Survey and the 1986 NAEP assessment obtained data on time spent on science and mathematics homework. In the National Survey, teachers of science and mathematics were asked to estimate the average amount of time a typical student in a randomly selected class spends on homework during the week. In the NAEP assessment, students in the 7th and 11th grades were asked to report how much time they spent on homework each week.

The findings show that the average amount of time spent on homework in both science and mathematics is relatively small but increases with grade level; also, more time is spent on mathematics homework than on science homework.[38] For instance, almost half of all high school students spend no time (12 percent) or less than 1 hour (36 percent) on science homework per week. Almost two-thirds of all students in the seventh grade spent less than 1 hour each week on science homework.

Analyses based on the 1986 NAEP assessment data show that a reasonably consistent relationship exists between the total amount of homework done and student proficiency in science and mathematics for grade 11 students, but not at the 7th grade. In both mathematics and science for the 11th graders, the more homework, the higher the proficiency. (See appendix table 1-32.) At the junior high school level, no consistent relationship appears to exist between homework and proficiency, although seventh grade students who reported spending no time each week on science homework had the lowest science proficiency.

INDICATORS OF TEACHING/EDUCATION QUALITY AND QUANTITY

The recent NRC report on precollege science and mathematics indicators pointed out that teacher quality and quantity was a key variable associated with student achievement. This section, accordingly, contains data on college courses teachers have taken as quality indicators. Teacher quantity is explored using data on supply and demand and teacher career patterns.

Teacher Preparation

In recent years, there has been considerable concern that teachers of science and mathematics may be poorly trained and/or inadequately prepared to teach these subjects. For example, a report by the American Association for the Advancement of Science states:

> "Few elementary school teachers have even a rudimentary education in science and mathematics, and many junior and senior high school teachers of science and mathematics do not meet reasonable standards of preparation in those fields."[39]

Furthermore, an NRC report prepared in response to the need to revitalize mathematics and science education, points out that:

> "Too often, elementary teachers take only one course in mathematics, approaching it with trepidation and leaving it with relief. Such experiences leave many elementary teachers totally unprepared to inspire children with confidence in their own mathematical abilities. What is worse, experienced elementary teachers often move up to middle grades (because of imbalance in enrollments) without learning any more mathematics."[40]

To address these issues, a special tabulation was prepared of course-taking data for teachers of science and mathematics. These teacher preparation data—taken from the 1985-86 National Survey of Science and Mathematics Education—were compared with the preservice standards recommended by the National Science Teachers Association (NSTA) and the National Council of Teachers of Mathematics (NCTM).[41]

Elementary School Teachers. NSTA has recommended that elementary teachers have at least one course in each of the three major areas of *science*—biological/life, physical, and earth/space—along with a course devoted to methods of teaching science. While large proportions of the elementary school teachers of science in the 1986 National Survey had taken at least one course in methods of teaching science (88 percent), biology (86 percent), the physical sciences (72 percent), and the earth/space sciences (44 percent), only 34 percent meet *all* of NSTA's recommended standards. (See appendix table 1-33.) Five percent of the teachers responsible for instruction of elementary science have had no college coursework in science; another 17 percent have had only one college science course; in most cases, this was a course in biology.

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[38] Despite the relatively small amount of time spent on mathematics homework by most students, reports by 13- and 17-year-olds indicate a dramatic increase in general homework being assigned each day, particularly between 1982 and 1986. In 1982, 73 percent of the 13-year-olds reported being assigned homework in general on a daily basis. This percentage increased to 96 percent in 1986. Results for 17-year-olds were similar, with 70 percent reporting assigned daily homework in 1982, compared to 94 percent in 1986. Data on trends in the amount of time spent on mathematics homework are not available. See NAEP (1988b), p. 107.

[39] AAAS (1989), p. 13.

[40] NRC (1989), p. 64.

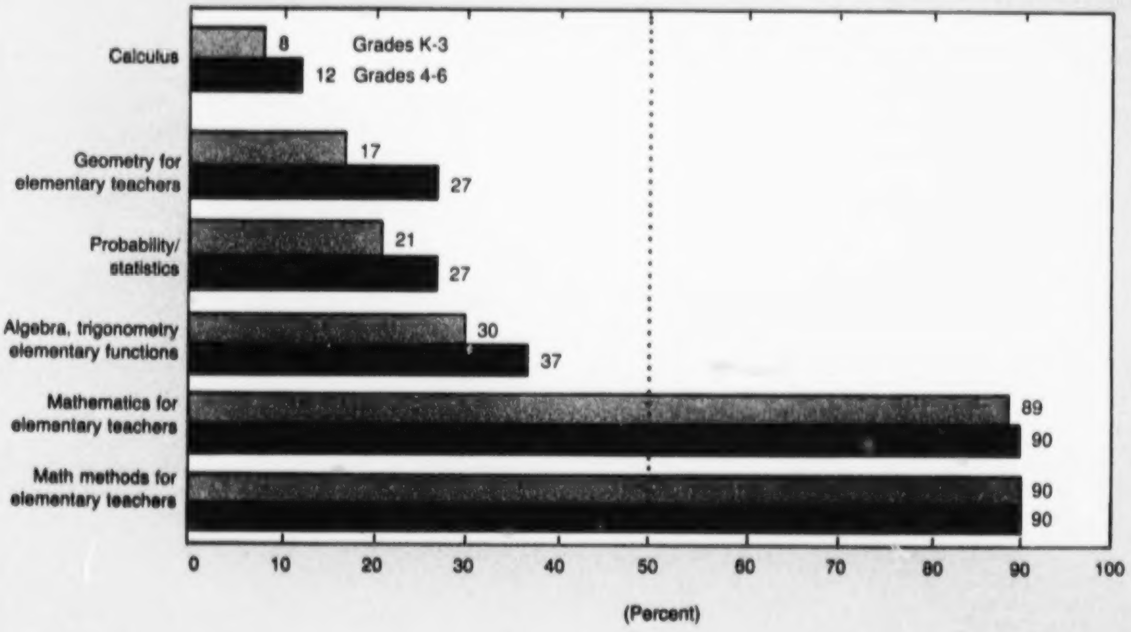
[41] Weiss (1988a) and (1988b).

NCTM recommends that elementary teachers of *mathematics* have at least one course each on (1) number systems through the rational numbers; (2) informal geometry including measurement, graphing, geometrical constructions, similarity, and congruence; and (3) methods of teaching mathematics.[42] While nine-tenths of elementary school teachers of mathematics have completed a course in mathematics for elementary school teachers, and an equal percentage have had a course in methods of teaching mathematics, less than one-fifth have completed an appropriate geometry course. (See figure 1-19.) Only 18 percent of elementary school teachers of mathematics meet all of NCTM's recommended standards. (See appendix table 1-34.) At the low end of the scale, 8 percent of these teachers have had no more than one of the three recommended courses.

Middle/Junior High School Teachers. NSTA has taken the position that teachers of *science* at the middle school level should be prepared as science generalists rather than as specialists in a particular science discipline. NSTA recommends that these teachers have a minimum of 36 semester credit hours in science, with at least 9 hours each of life, earth, and physical sciences, as well as a course in methods of teaching science. About two-thirds of all teachers of science in grades 7-9 meet the credit hours requirement;[43] however, only 22 percent have the specified distribution of science courses. (See appendix table 1-35.) An additional 2 percent meet the science standards but have not had a course in science teaching methods.

NCTM recommends that middle school teachers of *mathematics* have college coursework in five areas of mathematics (calculus, geometry, abstract algebra/number theory, applications of mathematics, and probability and statistics), computer science using a high-level programming language, and methods of teaching mathematics. Only 14 percent of grades 7-9 teachers of mathematics fully meet these standards. (See appendix table 1-36.)

Figure 1-19.
Percentage of elementary teachers who have ever completed selected college courses in math: 1986



SOURCE: Weiss (1988a).

Science & Engineering Indicators—1989

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[42] For the purposes of these analyses, any teacher who has completed a course in mathematics for elementary or middle school teachers, a course in geometry for elementary or middle school teachers, and a course in methods of teaching mathematics is considered to have met these requirements.

[43] Since most science courses are either 3 or 4 credit hours, the 36-hour recommendation by NSTA is roughly equivalent to 11 science courses.

High School Teachers. According to NSTA, secondary *science* teachers should have a minimum of 50 semester credit hours of coursework in science, with at least 32 hours (eight courses) of specifically designated courses in their area of specialty. Although a relatively high number of biology teachers meet the requirement of eight courses, only 29 percent of these teachers meet all of the NSTA recommendations. This is, in most cases, because they lack one or more of the specific biology courses listed. Similarly, less than one-third of the chemistry teachers, and only 12 percent of physics teachers, meet the full NSTA standards. (See appendix table 1-37.)

According to NCTM guidelines, high school *mathematics* teachers should have an extensive math background, including three courses each in calculus, linear algebra, abstract algebra, college geometry, probability and statistics, applications of mathematics, history of mathematics, as well as other upper-level coursework (e.g., applied mathematics from either classical continuous fields or the emerging discrete fields of mathematics). NCTM also recommends coursework in computer programming and methods of teaching mathematics. A total of 54 percent of grades 10-12 mathematics teachers come close to meeting these standards, typically lacking only one or two of the recommended mathematics courses and/or a course in computer programming. However, only 15 percent of secondary school math teachers meet all of the NCTM standards. (See appendix table 1-38.)

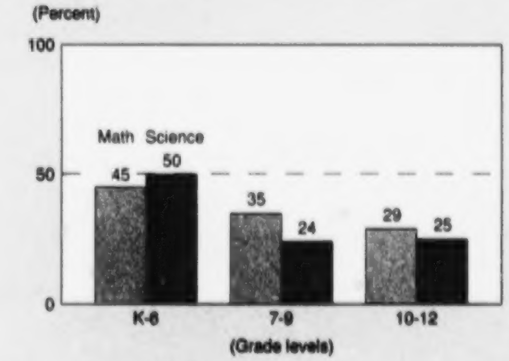
Professional Development of Teachers. Based on the inadequacies noted in science and mathematics preparation alone, there is considerable need for additional training of teachers. Moreover, the 1986 National Survey noted that from one-quarter to one-half of teachers had not taken a course in the subject they teach in the 10 years prior to the survey. (See figure 1-20.) Also, while many teachers participate in professional meetings, workshops, and conferences related to the subject they teach, the amount of time they devoted to these professional development activities was typically fewer than 6 hours during the previous 12 months.[44]

Teacher Supply and Demand

Over the past several years, numerous studies have pointed to a shortage of adequately trained teachers of science and mathematics, predicting that shortages will become worse over time as enrollments rise and the supply of new teachers falls.[45] Educational leaders have tried to respond to these conditions through such measures as differential pay for teachers in shortage areas (including science and mathematics), salary increases for teachers across all fields, and tuition support for teacher training and retraining. For example:

- The Houston school district provided incremental pay for all teachers designated in shortage categories from 1982 to 1987. Mathematics, science, and bilingual teachers were awarded the highest annual increments.
- New mathematics and science teachers were given higher initial salaries in Dade County, Florida.
- Salary contracts in Boston, Detroit, and Hartford contain provisions that allow new teachers in shortage areas to be paid more than their current experience would dictate.[46]

Figure 1-20.
Teachers with no college coursework in past 10 years in the subject they teach, by grade level: 1986



SOURCE: Weiss (1988a).

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The 1985-86 National Survey of Science and Mathematics Education asked principals to report on the difficulty of hiring qualified high school teachers.[47] The results show that over half the principals in the national sample said that their schools had trouble hiring fully qualified teachers in physics, chemistry, computer science, mathematics, and foreign languages. (See figure 1-21.) Rural high schools were more likely than suburban schools to experience difficulty in recruiting qualified mathematics, biology, earth science, special education, and general science teachers. This difficulty was especially apparent in certain subjects. In biology, for example—which is offered by nearly all high schools—half of the rural school principals said they had difficulty recruiting teachers versus only 13 percent of suburban school principals.

Career Patterns of Teachers, by Teaching Specialty

Until recently, very little has been known about teacher career patterns. How long does the average teacher stay in the teaching profession? How many teachers return to teaching after a career interruption? Do career patterns differ by teaching specialty? Recent research has attempted

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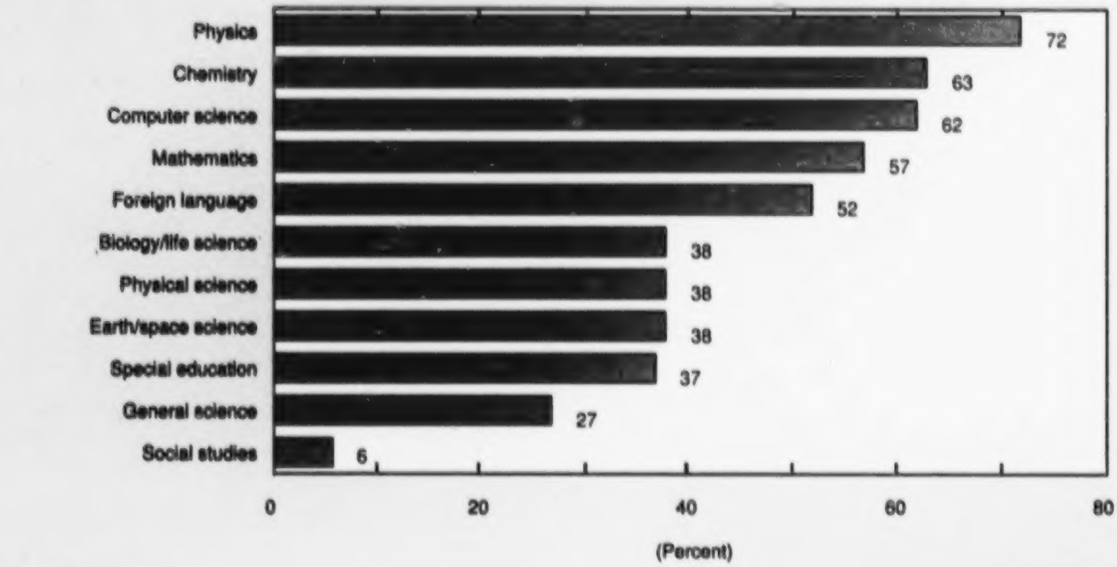
[44] Weiss (1987), p. 113.
[45] NRC (1987).
[46] Darling-Hammond (1988).
[47] Weiss (1987).

Figure 1-21.
Percentage of high school principals reporting difficulty hiring qualified teachers, by subject: 1986



SOURCE: Weiss (1987).

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to address these questions.[48] In these investigations, the career patterns of beginning teachers were tracked in three states (Michigan, North Carolina, and Colorado) as follows:

- During their initial employment—i.e., the *first spell*; and
- In cases where teachers left the field and returned to a teaching position at a later time, during this second period of employment as a teacher—i.e., the *second spell*.

The research revealed that attrition rates differ significantly for teachers with different subject matter specialties. In Michigan, for example, chemistry and physics teachers were more likely to leave teaching after only a few years in the classroom than were teachers in any other specialty. In fact, only 45 percent of the physics teachers, and 49 percent of the chemistry teachers, were still in the classroom 6 years after they started teaching. In contrast, by the end of 6 years, 61 percent of history teachers and 62 percent of biology teachers were still in the classroom.[49]

In all three states, high school teachers have shorter first-spell lengths than do elementary school teachers. (See appendix table 1-39.) And, among high school teachers, chemistry and physics teachers have shorter average first-spell lengths than teachers of other academic subjects. In both North Carolina and Michigan,[50] the average beginning teacher of chemistry and physics spent less than 5 years in the classroom, versus an average of around 7 years for teachers of social studies and mathematics.

In terms of those who return to teaching after a career interruption, chemistry and physics teachers again have the largest rates of attrition. Only 16.3 percent of the chemistry and physics teachers in North Carolina, and 14.6 percent of those in Michigan, returned to the classroom after initially teaching less than 6 years, compared with 22.6 percent and 22.5 percent, respectively, of the social studies teachers in each state. (See appendix table 1-40.)

Thus, chemistry and physics teachers have the shortest teaching careers. Not only do they leave teaching earlier than do teachers of other subject specialties, they are also less likely to return. This pattern suggests that, because of their higher rates of attrition, teachers of chemistry and physics will be in greater demand than other subject matter teachers in the future. And while teachers returning to the classroom will probably continue to be a significant source of future supply in some areas (e.g., elementary school teaching), they probably will not constitute a major source in chemistry, physics, and mathematics.[51]

EDUCATION REFORM MOVEMENTS

The continuing current high level of Federal and state policy concern with the performance of America's school children in science and mathematics was underscored by the unprecedented and widely publicized "Education

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[48] Murnane and Olsen (1989).

[49] Murnane (1987).

[50] Chemistry and physics teachers cannot be distinguished from biology teachers in the Colorado data.

[51] Murnane, Singer, and Willett (1988).

Summit" in September 1989, at which the President met with the governors of 49 states to endorse coordinated policies to improve precollege education.[52] This section highlights the various ongoing initiatives occurring at the state level to improve education quality.

State Reform Movements

During the 1980s, while various prestigious national commissions gathered to study the shortcomings of America's schools and to make recommendations to improve their performance, states also engaged their own review panels. Between early 1982 and mid-1983, states initiated 130 commissions or task forces to look at their own educational practices. By 1984, as many as 290 high-level state commissions were studying the quality of public education. The Education Commission of the States reported that many states had separate commissions working at the behest of the governor, state legislature, and the chief state school officer.[53] Findings, and the proposed and/or implemented solutions these findings have generated, are described in the following paragraphs.

Reforms in Student Preparation. In the area of student preparation, reform activities have been undertaken in setting curricular guidelines and raising curricular requirements for high school graduation and, at the elementary school level, raising the amounts of time devoted to science and mathematics instruction. Also, there is increased concern with assessment of student skills.

Although there is a great deal of variation from state to state, influence is generally exerted over the content of science and mathematics instruction through curricular frameworks, guides, textbook selection, and statewide assessment. Forty-seven states have curricular guidelines in science and mathematics: 27 states have recommended guidelines and 20 have required guidelines.[54]

Forty-six states raised curricular requirements in science and mathematics at the high school level during the 1980s.[55] By 1986, the average number of years of coursework required in science was 1.8 for public schools and 2.5 for private schools; comparable data for mathematics were 1.9 and 2.8 years. For both science and mathematics, the amount of coursework required is still short of the three credits recommended by the National Commission on Excellence in Education. (See figure 1-22.)

At the elementary school level, 25 states have recommended minimal amounts of time that should be devoted to science and mathematics instruction. At the lower elementary level, the range is from 20 to 30 minutes per day;

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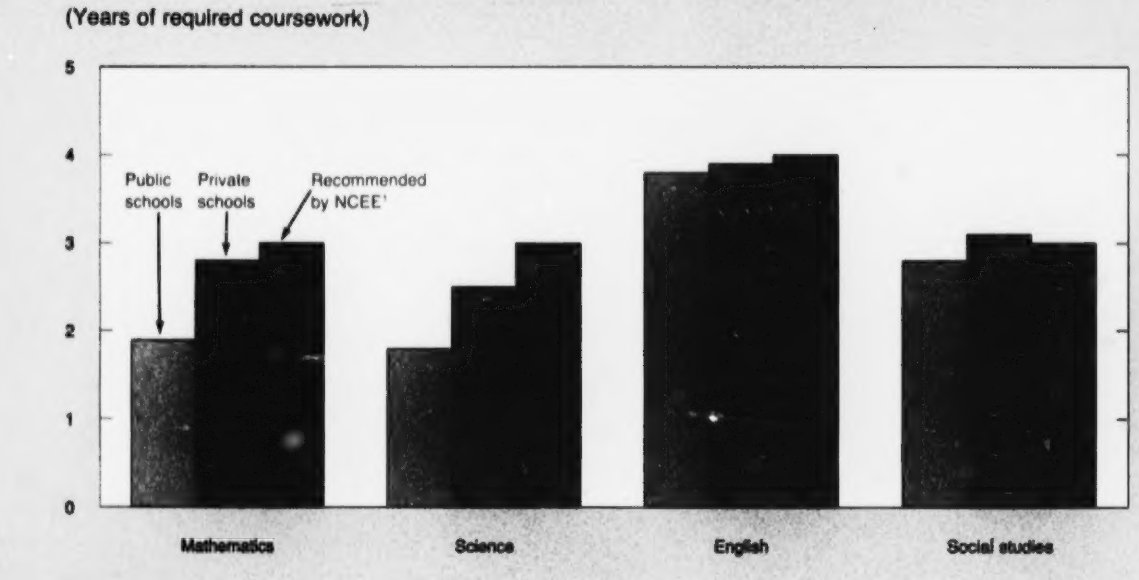
[52] See *New York Times* (1989).

[53] Kirst (1987).

[54] Moyer (1987), p. 1.

[55] Capper (1988), p. iv.

Figure 1-22.
Average years of coursework required for high school graduation, by subject area: 1985-86



¹National Commission on Excellence in Education.
SOURCE: NCES (1988).

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in upper elementary grades, the recommended amount is from 35 to 45 minutes per day. The recommendation for mathematics is approximately 15 minutes per day more at each level.

Almost every state has a statewide testing program of at least one grade level, primarily assessing basic skills of mathematics and reading or language arts. Assessment programs are growing, however, and 30 states now assess students' science knowledge and skills and 43 assess mathematics outcomes.[56]

Reforms in Teachers and Teaching. When asked to identify major problems that their states face in improving science and mathematics instruction, the majority of state-level policymakers point out concerns dealing with teachers and teaching.[57] Thirty states indicate a concern about teachers' understanding of science subject matter content and the ability to teach science so that students—especially young students—will comprehend scientific methodology. One need identified was that "elementary teachers need to more fully understand the use of hands-on, inquiry, and activity approaches in teaching science."

Teacher shortages is another issue of concern among the states—37 states reported a shortage of teachers in terms of either quality or quantity.[58] Other teacher issues included:

- Tendency of teachers to depend heavily on textbooks in teaching science and mathematics,
- Lack of adequate preservice preparation, and
- Lack of funding for staff development and teacher salaries.[59]

Regulation of the amount of science and mathematics course-taking required of prospective teachers varies considerably from state to state. Requirements are particularly low for prospective teachers of elementary grades. Approximately one-quarter of the states have no science or mathematics credit requirements for elementary-level teachers. Most states have course requirements in science or mathematics for middle/junior high school teachers (generally ranging between 12 and 36 semester credit hours in science or mathematics), but an occasional state has none and several leave this decision to the institutions offering certification programs. At the senior high level, almost all states have rather detailed specifications of required science or mathematics course work. One-half of the states do not require that secondary teachers take coursework in methods for teaching science or mathematics.[60]

Higher-order thinking skills (i.e., the ability to infer relationships and draw conclusions and to solve multistep problems) are of particular concern to many educational policymakers, and most states report activity in this area. Some states promote the teaching of higher-order thinking skills through staff development. For example, some states sponsor annual conferences for science and mathematics teachers on incorporating problem solving into their teaching. Some states have held in-service training programs statewide to promote the teaching of these skills, while others include these skills in their assessment programs. In still other states, higher-order thinking skills underlie and are the basis for their curriculum guidelines.[61]

New Institutional Arrangements. Only a handful of states provide sole support for magnet or residential schools that specialize in subject area study. Special schools are more often supported through private organizations or through a combination of resources. Fifteen states report sponsoring, at least in part, schools that focus on science; two more states say that they are considering or proposing a special, science-oriented school. Twelve states report having special schools that focus on mathematics; one state is currently proposing, and another currently developing, such a school. Some states report having more than one special school.[62]

The movement toward administrative and political decentralization of large urban public school systems, such as the Chicago system, will no doubt have a significant impact upon educational practice—including science and mathematics teaching. It is too soon yet to discern the details of the effects.

Impact of State Reforms on Local Schools

For state efforts at improving science and mathematics learning and achievement to be successful, they must be effectively implemented in local educational districts and schools. Two recent projects—one conducted by the Education Commission of the States (ECS), the second by the Center for Policy Research in Education (CPRE)—have studied the effect of state policies on local science and/or mathematics curricula. Study findings are described below.

The ECS project studied the local impact of various state policies designed to improve science curricula—e.g., adoption and improvement of state curriculum guidelines, selection of instructional materials, increased graduation requirements, increased instructional time, higher teacher certification requirements, assessment of student achievement, and evaluation of teaching. The study was conducted in California, Michigan, and Virginia as these states (1) encompass various mixes of policies and (2) form a continuum of state versus local control of education.[63]

The study found considerable evidence of positive impacts of state policy initiatives, but these were not uniform across states or districts. Among the 12 districts studied in depth, classroom impacts were detected in 8. At these sites:

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[56] Ibid., p. v.

[57] Armstrong, et al., (1988), p. 11.

[58] Moyer (1987), p. 12.

[59] Lack of funding was reported by 39 states as a major issue. Half of these states specifically cited lack of funding for materials and updating laboratories as a major problem.

[60] Capper (1988), p. vi.

[61] Moyer (1987), p. 2.

[62] Ibid., p. 5.

[63] Armstrong, et al., (1988). Within each state, researchers interviewed personnel in four school districts as well as in the respective state department of education. They visited three schools in each district, interviewing central office staff, principals, and teachers. These interviews became the basis of case studies and cross-site analyses.

- Increased time and emphasis were given to science instruction—especially in elementary school classes,
- Teachers made increased use of scientific experiments as instructional devices,
- Instructional materials were more available and of higher quality, and
- Instruction was better coordinated among grades.

Impacts were even more apparent at the district level in terms of official curriculum revisions, the content of in-service training sessions, and the adoption of textbooks. In districts where the implementation of state initiatives was successful, the researchers found strong leadership, centralization of curriculum revision, discretionary resources for materials and teacher training, science specialists at the district or school level, and attention paid to monitoring the implementation process.

In some districts (more than half of those in Michigan and Virginia), state science policies were apparently not adopted and consequently had no impact on classroom instruction. On-site visits to four districts in which impacts were generally absent provided a range of explanations, including the existence of unusually high-quality programs prior to the adoption of new state frameworks, a high degree of state autonomy, and rejection of state policies on philosophical grounds.

The CPRE study concentrated on high school graduation requirements.[64] Interview data on the intent and effects of these requirements were gathered in 4 states, 13 districts, and 19 high schools. Comparisons were made of graduation requirements in the core academic subjects of English, mathematics, science, and social studies.

The study findings showed that affluent schools and districts, which typically enroll large numbers of college preparatory students, were relatively unaffected by the reforms, usually because they already had graduation requirements that equaled or exceeded those mandated by the state. This applied to 4 of the 13 districts studied; these all tended to be affluent, suburban, and white.

Where district/school graduation requirements *were* increased, this generally resulted in the addition of mathematics and science courses. Out of 19 schools, 17 reported additions of mathematics and 16 reported additions in science. Moreover—while the ECS study found that hands-on activities were increasing in elementary school classes because of state reforms—the CPRE study found that, at the high school level, the courses added were overwhelmingly of the basic, general, or remedial type. This suggests that the impact of the reform initiatives was largely on middle- and low-achieving students. Of the 17 schools adding mathematics classes, 15 reported additions of basic, remedial, or general courses; this was true of 14 of the 16 schools adding science sections.

Thus, it appears that approximately half a decade after the implementation of a wave of state education reforms, their impact on science and mathematics instruction is yielding mixed results. Change is clearly under way; how far these changes will go, however, remains to be seen.

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[64] Clune (1988).

REFERENCES

American Association for the Advancement of Science (AAAS). 1989. *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology.* Washington, DC: AAAS.

Armstrong, J., et al. 1988. *The Impact of State Policies on Improving Science Curriculum.* Denver: Education Commission of the States.

Burstein, L. In press. "Pedagogical Practices and Student Heterogeneity." *SIMS: Student Growth and Classroom Processes in Lower Secondary Schools.*

Capper, J. 1988. "State Educational Reforms in Mathematics, Science, and Computers: A Review of the Literature." Report to the National Science Foundation.

Clune, W.H. 1988. *The Implementation and Effects of High School Graduation Requirements: First Steps Toward Curriculum Reform.* Madison, WI: Wisconsin Center for Education Research, University of Wisconsin-Madison.

The College Board. 1988. *Advanced Placement Program: National Summary Information 1987/1988.* Princeton: Advanced Placement Program.

Council of Economic Advisers. 1988. *Economic Report of the President.* Washington, DC: Government Printing Office.

Darling-Hammond, L. 1988. "Shortages of Mathematics and Science Teachers: Interpreting the Evidence." Special unpublished report to the National Science Foundation. The RAND Corporation.

Educational Testing Service (ETS). 1989. *ETS Policy Notes* 1, no. 3 (June). Princeton: ETS.

ETS Policy Information Center. 1989. *What Americans Study.* Princeton: ETS.

Ekstrom, R.B., M.E. Goertz, and D. Rock. 1988. *Education and American Youth.* Philadelphia: The Falmer Press.

Grandy, J. 1989. *Trends in SAT Scores and Other Characteristics of Examinees Planning to Major in Mathematics, Science, or Engineering.* Research Report No. RR-89-24. Princeton: ETS.

Hilton, T.L., J. Hsia, D.G. Solorzano, and N.L. Benton. 1989. *Persistence in Science of High-Ability Minority Students.* Research Report No. RR-89-28. Princeton: ETS.

International Association for the Evaluation of Educational Achievement. 1988. *Science Achievement in 17 Countries: A Preliminary Report.* Oxford: Pergamon Press.

Kirst, M.W. 1987. *Evaluating State Education Reforms: A Special Legislative Report.* Denver: Education Commission of the States.

Klein, M., and F.J. Rutherford, eds. 1985. *Science Education in Global Perspective: Lessons from Five Countries*. American Association for the Advancement of Science: Selected Symposium Series, no. 100. Boulder, CO: Westview Press, Inc.

Lapointe, A.E., N.A. Mead, and G.W. Phillips. 1989. *A World of Differences: An International Assessment of Mathematics and Science*. Princeton: ETS.

Moyer, K. 1987. *State Initiatives to Improve Science and Mathematics Education*. Denver: Education Commission of the States.

Murnane, R.J. 1987. "Understanding Teacher Attrition." *Harvard Educational Review* 57, no. 2 (May): 177-82.

Murnane, R.J., and R.J. Olsen. 1989. "Will There Be Enough Teachers?" *AEA Papers and Proceedings* 79, no. 2 (May): 242-46.

Murnane, R.J., and S.A. Raizen. 1988. *Improving Indicators of the Quality of Science and Mathematics Education in Grades K-12*. Washington, DC: National Academy Press.

Murnane, R.J., J.D. Singer, and J.B. Willett. 1988. "The Career Patterns of Teachers: Implications for Teacher Supply and Methodological Lessons for Research." *Educational Researcher* August-September: 22-30.

National Assessment of Educational Progress (NAEP). 1988a. *The Science Report Card: Elements of Risk and Recovery*. Report No. 17-S-01. Princeton: ETS.

———. 1988b. *The Mathematics Report Card: Are We Measuring Up?* Report No. 17-M-01. Princeton: ETS.

———. 1988c. *Computer Competence: The First National Assessment*. Report No. 17-CC-01. Princeton: ETS.

———. 1987. *Learning by Doing: A Manual for Teaching and Assessing Higher-Order Thinking in Science and Mathematics*. Princeton: ETS.

National Center for Education Statistics (NCES). 1988. *1988 Education Initiative*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

National Research Council (NRC), National Academy of Sciences. 1989. *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*. Washington, DC: National Academy Press.

———. 1987. *Toward Understanding Teacher Supply and Demand: Priorities for Research and Development - Interim Report*. Washington, DC: National Academy Press.

National Science Board (NSB), Commission on Precollege Education in Mathematics, Science, and Technology. 1983. *Educating Americans for the 21st Century*. CPCE-NSF-03. Washington, DC: National Science Foundation.

New York Times. 1989. "The Statement by the President and Governors." October 1.

Oakes, J., T. Ormseth, B. Bell, and P. Camp. (N.d.) *The Distribution of Opportunities to Learn Mathematics and Science*. Preliminary unpublished paper. The RAND Corporation.

Office of Technology Assessment (OTA). 1988a. *Elementary and Secondary Education for Science and Engineering—A Technical Memorandum*. Washington, DC: Government Printing Office.

———. 1988b. *Educating Scientists and Engineers: Grade School to Grad School*. OTA-SET-377. Washington, DC: Government Printing Office.

Raizen, S.A., and L.V. Jones. 1985. *Indicators of Precollege Education in Science and Mathematics: A Preliminary Review*. Washington, DC: National Academy Press.

Rock, D.A., R.B. Ekstrom, M.E. Goertz, T.L. Hilton, and J. Pollack. 1985. *Factors Associated With Decline of Test Scores of High School Seniors, 1972 to 1980*. CS 85-217. Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Weiss, I.R. 1988a. "Course Background Preparation of Science Teachers in the U.S.: Some Policy Implications." In A.B. Champagne (ed.), *Science Teaching: Making the System Work*. Washington, DC: American Association for the Advancement of Science.

———. 1988b. "Course Background Preparation of Science and Mathematics Teachers in the United States." Special report prepared for the National Science Foundation. Washington, DC: National Science Foundation.

———. 1987. *Report of the 1985-86 National Survey of Science and Mathematics Education*. Research Triangle Park, NC: Research Triangle Institute.

Westat, Inc. 1988. *Tabulations for the Nation at Risk Update Study as Part of the 1987 High School Transcript Study*. Washington, DC: National Center for Education Statistics, U.S. Department of Education.

Chapter 2

Higher Education for Science and Engineering

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Higher Education for Science and Engineering

HIGHLIGHTS

Between 1970 and 1987, institutions of higher education have increased in number and size.

- *Considerable growth was experienced by institutions offering the science and engineering (S/E) degree at some level.* Of the total 650 new institutions, about 400 offered the S/E degree at some level and about 70 awarded the science or engineering Ph.D. The most growth overall (in terms of all degree levels) was experienced in "comprehensive" institutions, which award relatively few S/E Ph.D.s, but considerable numbers of S/E baccalaureates and master's degrees. (See pp. 47-48.)
- *Ph.D.-granting institutions also award relatively high percentages of lower level S/E degrees.* While some 307 institutions offered the Ph.D. in 1986, 95 percent of all S/E Ph.D.s were awarded by 205 institutions. These same 205 also awarded 53 percent of the S/E baccalaureates and 72 percent of the S/E master's. (See p. 48.)

Freshmen continue to display declining interest in some S/E fields.

- *Fewer freshmen plan majors in engineering or computer science.* Between 1982 and 1987, the percentage of freshmen planning undergraduate degrees in engineering fell from 22 percent to 17 percent among men and from 4 percent to 3 percent among women. Both genders combined displayed declining interest in computer science majors, from 4 percent in 1982 to 2 percent in 1987. Interest in the physical sciences as a major has not changed. In contrast to these indicators, freshman full-time enrollments in engineering baccalaureate programs increased in 1988 for the first time in 6 years by about 2,500 students. (See pp. 49-51.)

Graduate S/E enrollments of U.S. citizens have not grown since 1986, while those of foreign citizens continue to increase.

- *In 1987, the long-term trend of increasing graduate enrollments of U.S. citizens in science and engineering programs halted, and these enrollments remained flat in 1988.* Fields experiencing absolute declines in U.S. citizens included engineering and the physical and environmental sciences. (See pp. 52-53.)
- *Enrollment of graduate students from abroad increased in virtually all fields in 1988, continuing a long-term trend.* In engineering, nearly 5 of every 10 students is a non-U.S. citizen, and 4 of 10 in the mathematical and computer sciences are from abroad. Since 1986, the entire increase (about 9,000 students) in graduate enrollments in S/E programs was accounted for by enrollments of non-U.S. citizens. (See p. 53.)

U.S. institutions continue to award more S/E Ph.D.s, especially to foreign citizens and to U.S. women.

- *Total S/E Ph.D.s awarded in 1988 increased by 945 degrees over 1987.* U.S. citizens accounted for one-third of this increase, halting a declining trend over the decade. Engineering showed the strongest gains among U.S. citizens. (See p. 53.)
- *Women U.S. citizens continue to earn increasing proportions of S/E Ph.D.s.* Among U.S. citizens, they earned 32 percent of S/E Ph.D.s in 1988, up from 17 percent in 1975, and were awarded 52 percent of non-S/E Ph.D.s. (See p. 55.)
- *Foreign citizens on temporary visas continue to earn increasing proportions of U.S. S/E Ph.D.s.* Foreigners on temporary visas earned 40 percent of engineering and mathematics Ph.D.s and 24 percent over all S/E fields. (See p. 55.)

Patterns of support for graduate S/E students have changed over the decade.

- *Non-Federal sources of support for graduate S/E study have increased faster than Federal sources.* However, the total number of students reporting mainly Federal assistance in their graduate S/E study in 1988 increased 4 percent over 1987. (See pp. 56-57.)
- *Institutional sources of support have grown most strongly throughout the decade.* In 1988, about 44 percent of graduate S/E students reported institutional support as their main source of support, versus 40 percent in 1980. (See pp. 56-57.)
- *Research assistantships have become the dominant mechanism of support.* Growth in research assistantships as the primary support mechanism has been about 5 percent per year since 1980. This mechanism of support now outnumbers all other support types, including "self-support." (See p. 57.)

More scientists and engineers employed on the Nation's campuses report research as their primary work activity. They are also older and hold higher rank, overall, than earlier in the decade.

- *Increases in "research intensiveness" on the Nation's campuses are evident since 1981.* This increase in research intensiveness, as opposed to teaching, was particularly strong in engineering, where 33 percent of the doctoral engineers in 1987—versus 23 percent in 1981—reported research as their primary work activity. (See pp. 58-59.)

- *U.S. S/E faculties hold higher ranks and have increased in average age.* The percentage of faculty holding full professorships reached as high as 58 percent in the physical sciences and 55 percent in engineering. These were also the fields with the highest proportions of teaching staff over the age of 50 in 1987, though all S/E fields have experienced declining proportions of younger faculty members since 1977. (See p. 59.)

This chapter discusses indicators of higher learning in science and engineering (S/E). These indicators are grouped into five general topic areas:

- The institutions that offer S/E degrees in the United States, with measures showing how the mix of these institutions has changed over the past few decades and which types of institutions offer S/E degrees at different degree levels and in different S/E fields;
- Information on students in these institutions, including limited data on undergraduate enrollments and plans for an S/E major, and more extensive coverage of graduate enrollments in S/E fields by various student subgroups;
- Recent S/E degrees awarded by these institutions, with trends in Ph.D. awards through 1988;
- Changes in how U.S. S/E graduate students finance their education; and
- Data on faculties in S/E higher education.

For the first time in the *Science & Engineering Indicators* series, the chapter opens the discussion of S/E higher education with an overview of the institutions in which this learning occurs. A recent reclassification of the 3,100 colleges, universities, and specialty schools in the United States permits tracking the changes in their different roles in S/E education since 1970. The distinct educational roles of the various categories of institutions become clear as groups of institutions are compared in terms of the levels and fields of S/E degrees they award.

Undergraduate enrollments in engineering programs and surveys of freshmen as they enter higher education are used as indicators of aspirations and intentions to obtain a science or engineering degree. The chapter then turns to data on S/E graduate enrollments in doctorate-granting institutions.

Degrees in science and engineering fields are indicators of achievement in learning, and these are the subject of the third section. The discussion pays particular attention to Ph.D. attainment among population subgroups and by U.S. citizens as a whole, reflecting ongoing concern of policymakers about these trends. For the first time in this series, this chapter separates out *U.S. citizen* Ph.D. earners by gender and racial/minority groups.

Financial support of students in S/E higher education is an indicator of the value society places on these endeavors, and the different sources and mechanisms of S/E graduate student support are the subject of the following section.

The chapter concludes with indicators of the faculties who teach and guide these students. These indicators concerning the professoriate are largely restricted to its teaching functions and general population characteristics; chapter 5 covers its research activities.

INSTITUTIONS IN S/E HIGHER EDUCATION

The approximately 3,100 institutions of higher education in the United States do not play equal roles in science and engineering education and research.[1] For example, in some fields, degrees awarded at the baccalaureate, master's, and Ph.D. levels are more concentrated in the Ph.D.-granting institutions than in other fields. Also, the number of institutions has expanded over the past two decades, and individual schools have developed into different types of schools as they have increased their program offerings to meet the demands of the growing student population.

A widely used classification of colleges and universities has been developed by the Carnegie Foundation for the Advancement of Teaching (1987).[2] The Carnegie classifications were initiated in 1970 and revised slightly in 1976 and 1987. They thus can be used to track changes over time in the general structure of the U.S. higher educational system as well as in individual institutions, including the relative roles of different institutional types in awarding S/E degrees.[3]

The foundation's classification scheme is based on a combination of factors, including:

- Amount of Federal support,
- Numbers and levels of degrees awarded and numbers of programs awarding such degrees, and
- An index of institutional "selectivity" (for the liberal arts institutions) developed from a number of measures.

Institutional Change Since 1970

Between 1970 and 1987, about 650 new institutions of higher education were established in the United States, bringing the total to about 3,100 institutions. (See appendix table 2-1.) Of these, approximately 2,400 offer an S/E degree at some level—i.e., from a 2-year (associate) degree to the doctorate.

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[1] This section focuses on the various educational roles played by these institutions. For discussions of their respective research and development activities, see chapters 4 and 5.

[2] The universe of institutions classified are those canvassed by the Higher Education General Information Survey of the National Center for Education Statistics, U.S. Department of Education.

[3] See Carnegie Foundation for the Advancement of Teaching (1987) for a similar discussion of institutional types broken out by total enrollment trends.

In discussing the roles of these institutions in awarding S/E degrees and how these roles have evolved since 1970, three aspects of change must be considered:

- Increases in the number of institutions awarding S/E degrees;
- Growth in the total number of institutions, especially at lower degree levels; and
- Expansion of institutions' programs, leading to subsequent reclassification.

During the period 1970-86, the number of institutions awarding the S/E Ph.D. increased by about 70 schools. By 1986, 300 institutions (13 percent) awarded S/E Ph.D.s. Half of this increase was accounted for by "comprehensive" and "other" schools, which offer relatively few Ph.D.s. (See appendix table 2-1.) In addition, the "doctorate-granting" classification grew by 35 universities over the 16 years; this primarily reflected the movement of comprehensive institutions into this category through program expansion and proliferation.

Much larger growth was experienced in the group identified as comprehensive institutions. One-hundred fifty schools were added to this category between 1970 and 1986 in response to several developments in higher education, including:

- Growth and expansion of programs in schools formerly identified as "liberal arts," and
- Growth of large statewide higher educational systems in the 1970s.

Comprehensive colleges may award few doctorates (see appendix table 2-2), but they produce large numbers of S/E baccalaureate and master's degrees.

The number of colleges in the liberal arts category that award S/E degrees has shrunk slightly—from 570 in 1970 to 532 in 1987—largely due to expansion of their programs and subsequent reclassification. This group of schools includes both nationally well-known, highly selective liberal arts colleges as well as a large group of colleges oriented to local industries and continuing education. About 10 percent of these schools offer master's degrees in one or more S/E fields.

The rapid expansion of 2-year colleges offering the associate degree is evident in appendix table 2-1. Over 200 of these colleges offering a technical degree were established between 1970 and 1986, bringing their total to 826 institutions.

"Specialized" schools offering a science or engineering degree doubled in number between 1970 and 1986. Most of these schools are in the health sciences.

S/E Degree Awards in 1986

A cross section of the 1987 Carnegie institutional classification, broken down by numbers and levels of S/E degrees granted in 1986, underlines the different roles of the institutional types in the science and engineering pipeline. Increasingly large proportions of all S/E degrees are granted by the 205 doctoral institutions (though some 307 institutions overall awarded S/E Ph.D.s). These 205 institutions grant almost all (95 percent) of the Ph.D.s, over half (53 percent) of the baccalaureates, and almost three-quarters (72 percent) of the master's degrees in science and engineering. (See appendix table 2-2.) Doctoral institutions also award 7 percent of all S/E associate degrees. Most of these latter, however, are granted by community colleges which, in 1986, awarded 77 percent of these 2-year degrees.

While liberal arts colleges constitute 37 percent of the institutions granting S/E baccalaureate degrees, they awarded only 9 percent of these degrees in 1986. These schools granted 1 percent of the master's and 2 percent of the associate S/E degrees.[4]

Institutional Classification and Degree Field

The roles of different classifications of institutions vary across broad S/E fields. (See appendix table 2-3.) For example, liberal arts colleges award few engineering bachelor's degrees (2 percent of the total in 1986). Engineering degrees at all levels are more often awarded by doctoral institutions, though the comprehensive institutions confer 26 percent of engineering baccalaureates and 13 percent of the master's degrees. (See figure 2-1.) Finally, a small group of specialized institutions award about 6 percent of engineering baccalaureates and 3 percent of the master's degrees.

In contrast to their negligible role in engineering education, liberal arts colleges grant 12 percent of science baccalaureates, reaching 17 percent in the physical sciences and 14 percent in psychology. The comprehensive colleges also grant relatively more science than engineering degrees (37 percent of science bachelor's, and 27 percent of science master's, degrees). Comprehensive institutions also produce relatively high percentages of mathematics and computer science degrees: 44 percent of the combined bachelor's and 29 percent of master's.

THE S/E STUDENT POPULATION

Changing Demographics

The size of the U.S. population groups normally attending institutions of higher education is declining. For example, 18- to 21-year-olds—the traditional undergraduate student cohort—have been declining in number since 1981. (See appendix table 2-4.)

Decreases in the indicators discussed here may reflect this changing size of the relevant population group; they might also reflect changing choices of individuals. Thus, attention should be paid to changing *rates* as well as to absolute measures.

For example, the data in appendix table 2-4 show that there is not a continuous direct relationship between

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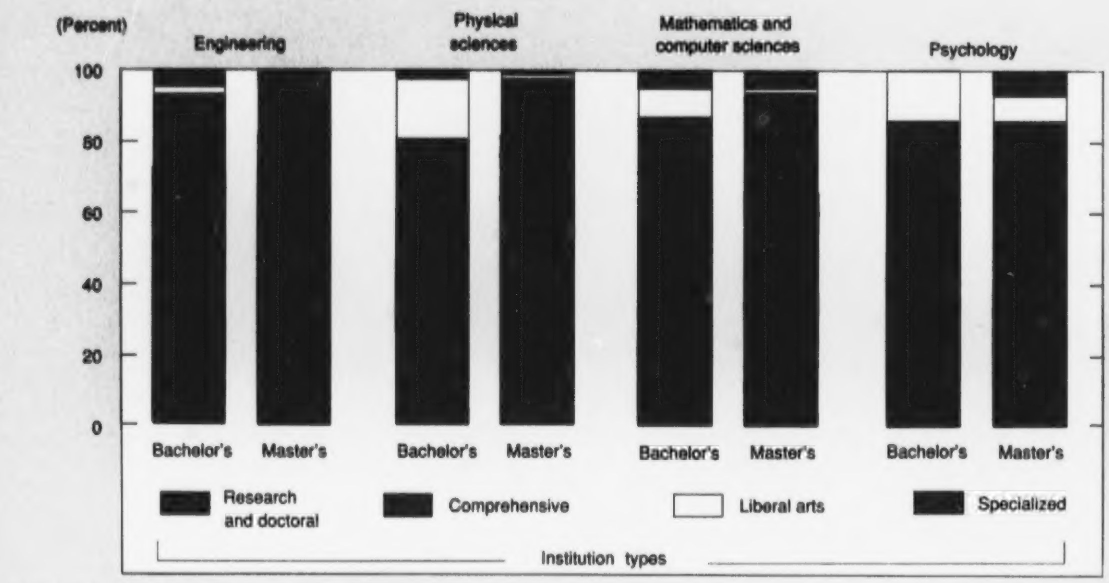
[4] See NSB (1987), pp. 47-48, for a discussion of the major role these institutions play in producing baccalaureate recipients who go on to earn S/E Ph.D.s.

Figure 2-1.
S/E bachelor's and master's degrees, by field and institution type



See appendix table 2-3.

Science & Engineering Indicators—1989

demographic trends and enrollment in colleges and universities. Enrollments of 18- to 21-year-olds have not declined as rapidly as the size of that population group; thus, the college-going rate of the group has increased overall.[5] Consequently, the observations in this section are based on trends over time and not on annual fluctuations. These increases, especially among women (both black and white), have helped compensate for the decline in the cohort size to keep enrollments high at U.S. colleges and universities.[6] Also, growing proportions of U.S. high school graduates overall pursue higher education, a trend that has been sustained for at least a decade. (See figure 2-2.)

Indicators for certain population subgroups contrast with the overall trend. Black males aged 18 to 21—after increasing their college enrollment rates by about 5 percentage points from 1980 to 1985—more recently have failed to increase alongside the overall cohort; they may actually have begun to decline. Likewise, attendance rates of 18- to 21-year olds of Hispanic origin show little, if any, increase. (See appendix table 2-4.)

Freshman Plans

Engineering Enrollments. Most undergraduates planning a degree in the sciences need not declare their major field until the second or third year of study. In contrast, the engineering bachelor of science is a 4- or 5-year professional curriculum starting in the freshman year; headcounts of students in these programs provide early indicators of freshman plans. Surveys by the Engineering Manpower Commission provide trend data on the full- and part-time enrollments in both baccalaureate and shorter programs.[7]

In the fall of 1988, approximately 346,000 students were enrolled full time in an engineering baccalaureate program. (See appendix table 2-5.) Freshman full-time enrollments in the 4- and 5-year programs, after decreasing for 5 years, increased in 1988 by about 2,500 students. (See figure 2-3.) Total part-time enrollments in these programs also increased. Since some of these part-time students are midcareer and may be returning to class for specific courses only, it is unclear how many of these students intend to obtain a degree. In 1988, part-time enrollments were 11

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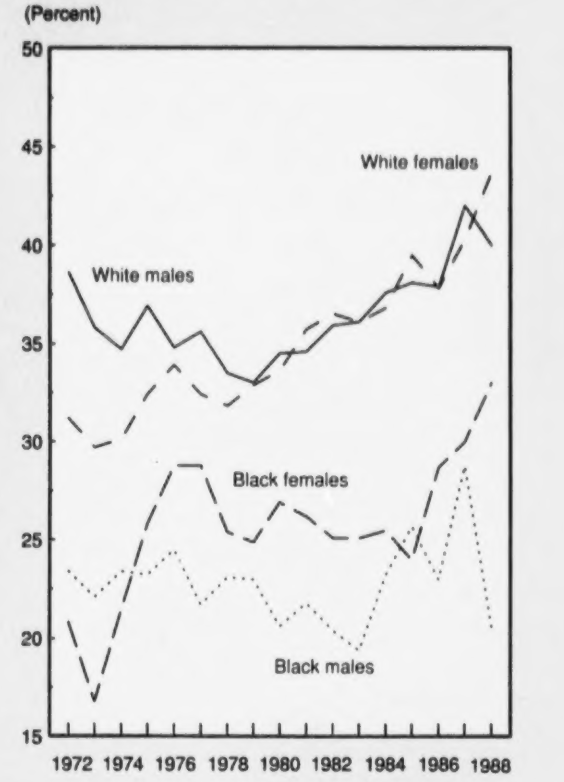
[5] As estimated in the U.S. Bureau of the Census' Current Population Survey (CPS) conducted each October. CPS is a survey of approximately 60,000 households, covering about 125,000 people and 8,000 college students. Some of the detailed categories in these data are necessarily small, and trend data based on them are subject to considerable year-to-year fluctuations.

[6] Significant differences in these trends are likely to exist among individual institutions, across fields, and in various geographic regions.

[7] American Association of Engineering Societies (1989). The data on engineering programs are from 4- and 5-year programs approved by the Accreditation Board of Engineering and Technology (ABET). Upon successful completion of these programs, the student receives a bachelor of engineering degree or, in the case of the 5-year programs, an engineering professional degree. Engineering technology enrollments, in contrast, are usually in 2-year programs terminating in an associate degree, but some of these programs also include 4-year study. Data on engineering technology enrollments in appendix table 4-5 are from all programs, not just ABET-approved programs.

Figure 2-2.
College attendance rates of 18- to 21-year-olds



See appendix table 2-4. *Science & Engineering Indicators—1989*

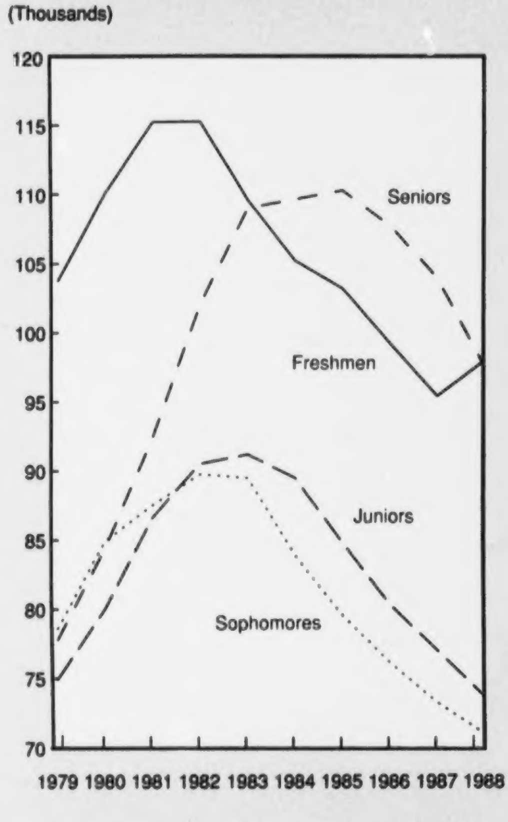
percent of full-time enrollments, and this ratio has hardly changed over the decade.

Enrollments by freshman blacks increased from 5,800 to 6,100 from 1986 to 1987, and total black undergraduate enrollment increased from 16,800 to 17,300.[8] Hispanics, too, increased their freshman enrollment in engineering curricula from 4,300 to 4,500 and from 16,300 to 17,100 overall. Students of Asian origin increased 10 percent among engineering freshmen (to 7,100) and 12 percent overall (to 30,100).

Engineering Technology Enrollments. Full-time enrollments in engineering technology programs—at both the associate and bachelor's levels—declined throughout the 1980s. (See appendix table 2-5.) However, part-time enrollments in these programs have shown recent growth, possibly reflecting increasing midcareer study. The growing number of engineering technology programs (from 200 in 1985 to 310 in 1988) suggests that schools are developing programs to accommodate students who cannot study full time.

The 1987 Freshman Class.[9] Declining enrollments in engineering are being driven not only by decreases in the size of the 18-year-old population but also apparently by reduced interest in the field among students in successive freshman classes. Between 1982 and 1987, the percentage of freshmen planning a baccalaureate in engineering declined from 12.6 percent to 9.4 percent. (See figure 2-4.) Both male and female interest in engineering majors is falling: among men, from 22.3 percent in 1982 to 17 percent

Figure 2-3.
Undergraduate engineering enrollments



See appendix table 2-5. *Science & Engineering Indicators—1989*

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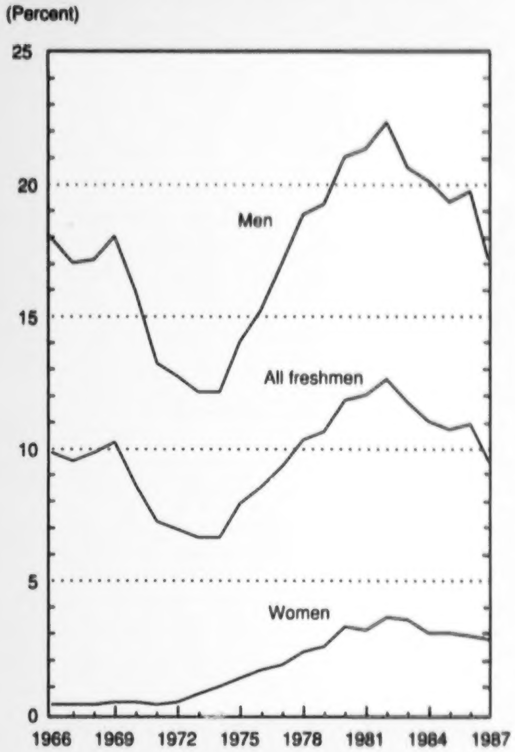
[8] The data in this paragraph are from Ellis (1988).

[9] Data in this section are from the University of California at Los Angeles (UCLA) Cooperative Institutional Research Program, which each fall surveys entering freshmen on various characteristics and their future plans. Excluded from this survey are part-time freshmen and students who have previously attended college for credit. The data also exclude students at semiprofessional and proprietary schools, as well as those at certain very small schools. Data here are from UCLA (1982-87), or—when so cited—special unpublished tabulations. (In the latter case, only freshmen at 4-year colleges and universities are included.) For a complete description of the survey methodology, see any of the UCLA volumes.

Figure 2-4.
Freshman plans to major in engineering



SOURCE: UCLA. *Science & Engineering Indicators—1989*

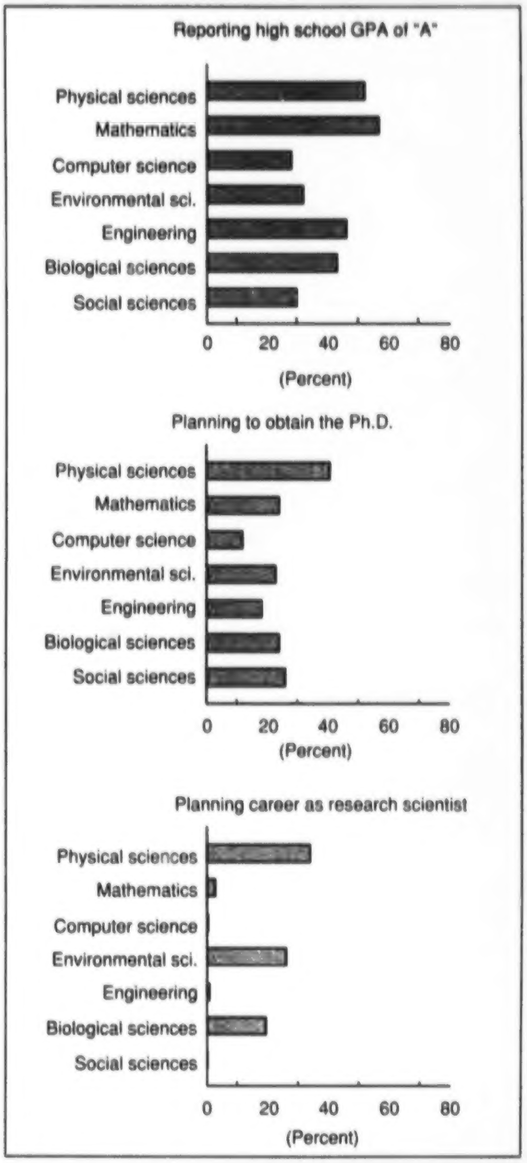
in 1987, and among women from 3.6 percent to 2.7 percent.[10]

Freshman plans for a major in computer science have also fallen, dropping from 4.4 percent in 1982 to 1.6 percent in 1987 (both genders combined). (See text table 2-1.) Increases in both the biological sciences and social sciences as planned majors have been noted in the UCLA surveys. (See footnote 9.)

In the nonscience fields, business has remained the major of choice for about 25 of every 100 freshmen since 1982; the arts and humanities, however, have increased as a major choice, rising from 8.2 percent in 1982 to 11.3 percent in 1987. Student plans also indicate a trend noted in *Science & Engineering Indicators—1987*:[11] over all fields, more freshmen are planning to study longer and obtain a higher degree. (See text table 2-1.)

When freshmen planning science or engineering degrees are broken down by broad field categories, differences emerge on self-reports of high school grade point averages (GPA), aspirations to the Ph.D., and career plans. (See figure 2-5.)[12] For example, less than one-third of students planning degrees in the environmental, computer, and social sciences report a high school GPA of "A," while

Figure 2-5.
Freshman plans and characteristics, by selected planned undergraduate major



SOURCE: UCLA, Higher Education Research Institute, unpublished tabulations.

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[10] Data on freshman plans for engineering majors from another source, the Admissions Testing Program of the College Board, are reported in Lane (1988).

[11] NSB (1987), p. 41.

[12] NSB (1985), pp. 98-100.

Text table 2-1. Freshman plans

	1982	1983	1984	1985	1986	1987
	Percent					
Highest degree planned						
Ph.D. or Ed.D.	8.2	8.5	9.2	9.2	9.7	13.2
Master's	30.5	30.4	31.2	31.6	33.0	39.2
Bachelor's	38.3	36.5	37.6	38.2	36.8	31.5
Probable major						
Biological sciences	3.7	3.8	4.2	3.4	3.9	4.4
Engineering	12.6	11.7	11.0	10.7	10.9	9.4
Physical sciences[1]	2.5	2.5	2.6	2.4	2.4	2.6
Social sciences	5.8	6.1	6.7	7.6	8.0	10.1
Computer science	4.4	4.5	3.4	2.3	1.9	1.6
Business	24.2	24.4	26.4	26.8	26.9	25.7
Education	6.0	6.0	6.5	7.1	8.1	8.8
Arts and humanities	8.2	7.9	7.7	8.3	9.0	11.3
One of the professions	13.3	14.4	14.1	12.9	11.7	10.7
Probable career occupation						
Computer programmer or analyst	8.8	8.5	6.1	4.4	3.5	2.4
Scientific researcher	1.5	1.5	1.5	1.4	1.4	1.8
Engineer	12.0	10.8	10.4	10.0	9.7	8.4
College teacher	0.2	0.2	0.3	0.3	0.3	0.3

[1] Includes mathematics.

SOURCE: UCLA (1982-87).

See figure O-14 in Overview.

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over half of those anticipating majors in the physical sciences and mathematics report this level of performance. Regarding plans for the Ph.D., 41 percent of freshmen planning baccalaureates in the physical sciences hope to attain the doctorate, as do about one-fourth of freshmen looking to a bachelor's in mathematics or the environmental, biological, or social sciences. In sharp contrast, only about 12 percent of freshmen planning an undergraduate degree in computer science state that they hope to attain the Ph.D.

Depending on their field of interest, freshmen planning S/E degrees differ greatly in their plans for a career as a "research scientist." One-third of freshmen anticipating physical science majors, one-fourth of planned environmental science majors, and one-fifth of planned biological science majors foresee a future as a research scientist (35 percent of the latter plan to enter the medical profession). Three percent of freshmen hoping to attain a bachelor's in mathematics plan to become research scientists, and less than 1 percent in computer and social sciences and in engineering have such plans.

Merit Scholars. Another indicator of freshman plans can be obtained from the stated choice of major of Merit Scholars.[13] While the percentage of scholarship winners who have planned a major in science or engineering has varied over the years, recent trends are downward. (See appendix table 2-6.) Proportions choosing engineering, the sciences overall, and the health sciences are declining; simultaneously, more Merit Scholarship winners are planning majors in the social sciences and humanities. (See figure 2-6.)

Graduate Enrollments[14]

Enrollments of U.S. citizens in graduate science and engineering programs have not increased since 1986. In contrast, students from abroad continued to enroll in these programs in increasing numbers: in 1988, one in four graduate students studying science and engineering in U.S. universities was from abroad.

Other changes are occurring among the graduate S/E student population and the institutions they attend. Decreases in part-time enrollments, and sharp differences in enrollment rates among fields of study, become apparent when overall enrollment data are disaggregated. More women undertake graduate S/E study, and the various racial and ethnic groups display different patterns of

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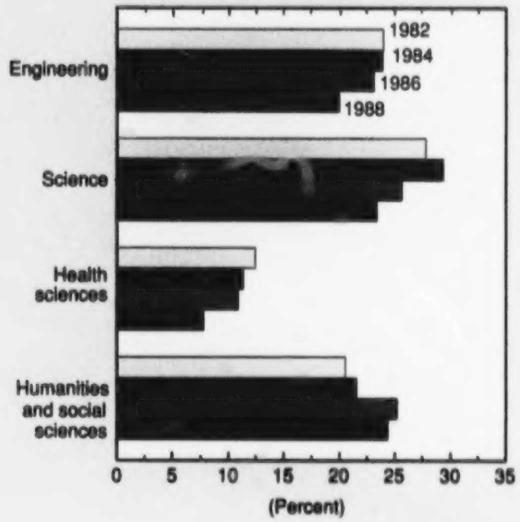
[13] NSB (1977), p. 159. Merit Scholarships are competitive grants administered by the National Merit Scholarship Corporation, Evanston, Illinois. For a complete description of the program, see National Merit Scholarship Corporation (1982-88).

[14] The graduate enrollment data discussed in this section are limited to enrollments in S/E doctorate-granting institutions. These enrollments accounted for 85 percent of all graduate enrollments in 1987 and about 93 percent of total full-time enrollments. For details of the survey universe and student populations, see NSF (1989a).

Figure 2-6.
Choice of major of Merit Scholars



See appendix table 2-6.

Science & Engineering Indicators—1989

enrollment. These and other trends are discussed in the following paragraphs.

Overall S/E Enrollments. In 1988, total enrollments in all S/E fields combined increased by 1 percent over the previous year, a slowing of the 1980-86 trend of an annual 2-percent increase. (See figure O-15 in Overview.) Virtually all of the 1988 growth in total enrollments was in the sciences; graduate engineering enrollment has remained unchanged for 3 years.

Enrollments by Citizenship. Graduate S/E students who are U.S. citizens increased by 1,300 students in the sciences in 1988, but decreased in engineering by 1,400. (See appendix table 2-8.) Other fields experiencing absolute declines in the number of U.S. citizens enrolled were the environmental sciences (5.6-percent drop)[15] and the physical sciences (0.6 percent).

Foreign enrollments increased in all S/E fields, continuing a trend that has been widely noted and discussed.[16] In full- and part-time study combined, increasing matriculation in science and engineering programs by non-U.S. citizens accounted for the entire growth in enrollments from 1987 to 1988. (See text table 2-2.)

Non-U.S. citizens are attracted to particular fields of study. In 1988, nearly 5 of every 10 full-time engineering students in doctorate-granting institutions were non-U.S. students. (See figure O-16 in Overview.) In the science fields, foreign students made up 37 percent of enrollments in the physical sciences and about 43 percent in both the mathematical and computer sciences.

Text table 2-2. Graduate S/E enrollments by citizenship and enrollment status

	Full-time	Part-time	Total
	—Percent change 1987-88—		
Total enrollment	1.9	-0.2	1.2
Total U.S. citizens	0.3	-0.6	-0.03
Foreign citizens	5.5	2.9	5.2

Note: Includes only doctorate-granting institutions.

See appendix tables 2-8 and 2-9.

Science & Engineering Indicators—1989

Enrollments by Gender. Women have traditionally specialized in the sciences or engineering at rates below those of men. Thus, this large population group has become a focus of attention for policymakers and educators concerned with future supplies of scientific and engineering personnel.[17]

Enrollments of women in graduate S/E programs continued to increase in 1988, and the rate of increase overall is higher than earlier in the decade.[18] By contrast, in engineering, increases averaging 10 percent yearly from 1980 to 1987 slowed to 3 percent in 1988. (See appendix table 2-7.) In both time periods, however, the rates of increase for women exceeded those of men. Women make up about 32 percent of the total graduate S/E enrollment and earn about 32 percent of the doctorate S/E degrees awarded to U.S. citizens.

Like other population groups, women tend to concentrate in certain broad fields. They make up particularly large proportions of total graduate enrollments in psychology (63 percent), the social sciences (47 percent), and the life sciences (41 percent). (See appendix table 2-7.) While they account for smaller proportions in the physical sciences (22 percent), mathematics (29 percent), and engineering (13 percent), their enrollments have been increasing faster in these fields.[19]

Enrollments by Racial/Ethnic Group. The extent to which different population subgroups—e.g., women, some minorities, and older students[20]—choose careers in engineering and science has attracted increasing attention. For example, a recent survey of campus administrators reports that many of them perceived their institution's performance in attracting minority students as "fair" or "poor."[21]

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[15] The environmental sciences in these data include atmospheric sciences, geosciences, and oceanography.

[16] See, for example, NRC (1988b); and NSF (1986).

[17] For discussions of women at other points in the scientific and engineering pipeline, see the appropriate sections in other chapters of this report. Detailed data are presented in the biennial series *Women and Minorities in Science and Engineering*; for the most recent volume, see NSF (1990). A recent discussion of issues involving women in science and engineering can be found in NSF (1987b).

[18] The statistics discussed in this section obscure the nationality of the men and women described; the questionnaire from which these data are produced does not allow for classifying by gender and nationality. However, because most non-U.S. citizens enrolled in S/E graduate programs are men, the enrollment data for women discussed here may be assumed to include mostly U.S. citizens. Conversely, the enrollment data for men in this section include much of the enrollment by non-U.S. citizens.

[19] In general, graduate S/E fields that attract relatively fewer women than men also tend to be fields with high enrollment of non-U.S. citizens. If the assumption is correct that most of these students are male, then the enrollment rates of females in these fields among students who are *U.S. citizens* could be expected to be higher than identified here.

[20] A recent study of characteristics of students 25 and older is reported in Aslanian and Brickell (1988).

About 600 more black U.S. citizens enrolled in graduate S/E programs in doctorate-granting institutions in 1988 over 1987. (See appendix table 2-8.) These increases were spread across all fields, except for a 6-percent decrease in mathematics (about 20 students). Among U.S. citizens in engineering programs, only 1 student in 50 is black.

Enrollments of white U.S. citizens, though relatively unchanged overall, decreased by 3 percent in engineering programs. (See appendix table 2-8.) S/E graduate students of Hispanic origin (U.S. citizens only) have increased their enrollment rates throughout the sciences and engineering in the 1980s; this trend was halted in 1988. Enrollments of U.S. citizens who identify themselves as of Asian background continue to increase in virtually all fields. (See appendix table 2-8.) Overall, the rate of enrollment growth of this population group was 9 percent in 1988. The largest increase for citizens of Asian origin was in the physical sciences (22 percent).

Part-Time Enrollments. *Science & Engineering Indicators—1987* noted strong growth in the number of graduate students in science and engineering who study part time.[22] In 1988, this decade-long trend may have ended. Part-time graduate enrollments in engineering—especially among U.S. citizens—largely accounted for the slowdown.[23] (See appendix table 2-9.)

Enrollments by Field. As noted above, the sciences continued to grow in total graduate enrollments in 1988 over 1987 while engineering enrollments remained unchanged. Among science fields, only the environmental sciences lost enrollment; this continued a 4-year trend in this field. In contrast, the mathematical sciences have experienced strong enrollment growth throughout the decade, especially because of enrollments by non-U.S. citizens. Other fields with strong growth in 1988 were computer science and psychology; both showed a 3-percent increase.

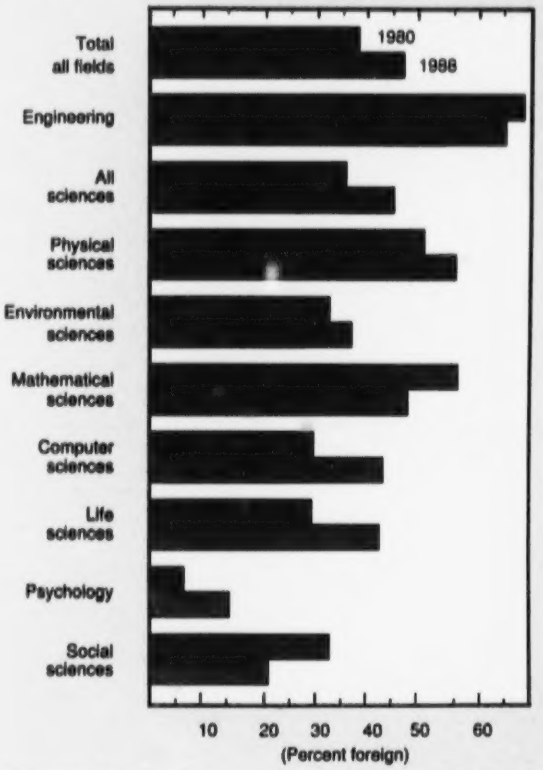
Postdoctoral Appointments[24]

In 1988, about 20,000 researchers held postdoctoral training positions in U.S. research universities. About 1,700 of these were in engineering fields, but this number has been increasing annually by about 8 percent since 1980. (See appendix table 2-10.) In contrast, the number of postdoctorates in scientific fields has grown at an annual rate of about 5 percent over the same period.

Postdoctoral appointments generally grow in conjunction with expanding academic research budgets, and this has been the case throughout the 1980s.[25] In the life sciences, where most (57 percent) of these positions are located, positions increased 11 percent in 1988 over 1987.

Foreign citizens increasingly receive postdoctoral appointments. (See figure 2-7.) Their percentage of all positions in the life sciences increased from 30 percent in 1980 to 42 percent in 1988. In engineering, non-U.S. citizens hold 66 percent of the postdoctoral positions, though this percentage has not changed considerably since 1980. Total postdoctoral appointments held by foreigners have also grown faster than those held by U.S. citizens: about 8 percent versus 3 percent per year, respectively, since 1980.

Figure 2-7.
Foreign S/E postdoctorates, by field: 1980 and 1988



See appendix table 2-10. *Science & Engineering Indicators—1989*

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[21] See El-Khawas (1988).

[22] NSB (1987), p. 43.

[23] Relatively few foreign students attend graduate S/E programs part time, largely because of visa regulations.

[24] Data for this section are from NSF, Survey of Graduate Science and Engineering Students and Postdoctorates. Postdoctorates include those individuals with science or engineering Ph.D.s, M.D.s, D.D.S.s, or D.V.M.s (including foreign degrees that are equivalent to U.S. doctorates) who devote *their primary effort* to research activities or study in the department under temporary appointments carrying no academic rank. Such appointments are generally for a *specific time period*. Postdoctorates may contribute to the academic program through seminars, lectures, or by working with graduate students. Clinical fellows, and those with appointments in residency training programs in medical and health professions, are not included unless the primary purpose of the appointment is research training under the supervision of a senior mentor. See NSF (1987), p. 44.

[25] See chapter 4. NRC (1988a) provides detailed data on postdoctorates by fine field.

SCIENCE AND ENGINEERING DEGREES

Overall Degree Trends

Ph.D.s in S/E fields accounted for 60 percent of all doctorates awarded in 1988—an increase of 5 percentage points over the past decade. (See appendix table 2-11.)

The total of S/E doctorates awarded by U.S. universities increased in 1988 over 1987 by about 945 degrees. The sciences and engineering each accounted for about half of this increase. (See appendix table 2-12.) Only Ph.D.s in the social sciences and psychology failed to increase.

The last year for which data on bachelor's and master's degrees is available is 1986.[26] Undergraduate awards in science and engineering combined increased from 1985 to 1986 by 2,500 degrees, to a total of about 324,000 degrees. (See appendix table 2-11.) This was 30 percent of all baccalaureates awarded in the U.S., a ratio that has not changed for 3 years. Baccalaureate awards declined in the physical sciences, environmental sciences, and life sciences. Eight hundred fewer students received engineering bachelor's degrees in 1986 than in 1985.

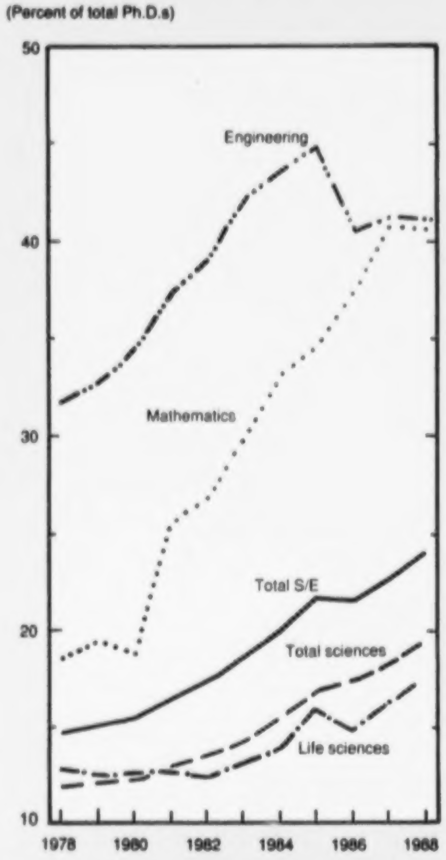
Doctoral Degrees by Citizenship

Following a declining trend for most of the decade, U.S. citizens earned about 300 more Ph.D.s in the sciences and engineering in 1988 than in 1987. (See appendix table 2-14.) Most of these increases were in engineering (220 degrees), continuing a 5-year trend.

Ph.D.s earned by foreign citizens on temporary student visas account for a growing share of total Ph.D.s awarded by U.S. institutions in most broad science and engineering fields. This phenomenon has attracted widespread attention, leading to speculation about the impacts of this increasing presence of non-U.S. citizens on higher education, future supplies of doctoral scientists and engineers for the U.S. labor market, and the wisdom of relying on immigration of doctoral scientists.[27]

Across the sciences and engineering combined, non-U.S. citizens on temporary visas earned 24 percent of the Ph.D.s in 1988, up from 15 percent a decade ago. (See figure 2-8.) In both the mathematical sciences and engineering, temporary visa-holders earned 40 percent to 41 percent of the Ph.D.s in 1988. Also in that year, non-U.S. citizens earned 25 percent of the Ph.D.s in the social sciences. (See appendix table 2-13.)

Figure 2-8.
S/E Ph.D.s awarded to foreigners



Note: Includes only foreigners on temporary visas.
See appendix table 2-13. *Science & Engineering Indicators—1989*

Ph.D. Degrees by Gender

The share of total degrees in the sciences and engineering earned by women has remained at about 26 percent for 3 years. (See appendix table 2-11.) Since the majority of the S/E Ph.D. earners from abroad are male, the heavy proportion of non-U.S. citizens in this ratio hides the relative shares of male and female U.S. citizens. When Ph.D.s awarded to foreigners are removed from the total figures, the share of degrees earned by *U.S.* female citizens increases considerably.

In all non-S/E fields, U.S. females earned 52 percent of the Ph.D.s awarded in 1988. (See figure 2-9.) They earned 32 percent of the S/E doctorates awarded to U.S. citizens in 1988, up from only 17 percent in 1975. In 1988, U.S. female citizens earned 10 percent of the engineering doctorates awarded to U.S. citizens and 36 percent of the corresponding science doctorates. However, women are increasing their rates of obtaining the engineering Ph.D. faster than men, about 16 percent per year versus 7 percent per year over the past 4 years. Women's shares of Ph.D.s in both psychology and the life sciences—where they have always been well represented—have increased from 32 percent to 55 percent and from 21 percent to 35 percent, respectively, since 1975. (See appendix table 2-14.)

Ph.D.s by Racial/Ethnic Group

Over the past decade, black U.S. citizens have been earning fewer Ph.D.s in science and engineering: in 1988,

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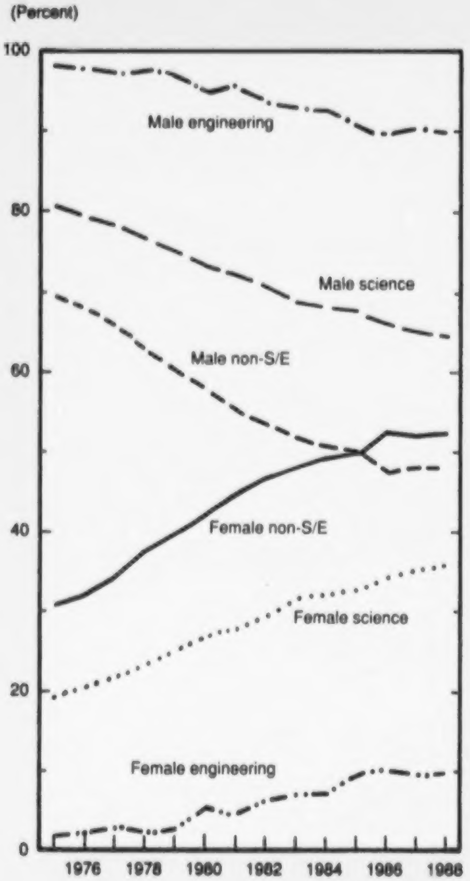
[26] For data on degrees using the categories of "job-related" versus degrees in the arts and sciences, see Carpenter (1987).

[27] For example, see NRC (1988b), especially the essays by Drucker, Kuswa, and Luco; and NSF (1986).

Figure 2-9.
Ph.D.s earned by U.S. citizens, by gender



See appendix table 2-14. *Science & Engineering Indicators—1989*

they received 231 such degrees compared with 278 in 1978. (See appendix table 2-15.) Ph.D.s awarded to black female citizens declined in 1988 for the fourth year in a row, though black female citizens earned 390 non-S/E Ph.D.s in 1988 versus 337 in 1987. Black male citizens earned 127 S/E Ph.D.s in 1988. While this was a slight increase over 1987, it was down considerably compared to the late 1970s. In contrast, Ph.D.s earned by Hispanic citizens doubled over the same period, from 160 to 319.

White U.S. citizens earned 299 more Ph.D.s in the sciences and engineering combined in 1988 over 1987. This accounted for almost all of the increase in Ph.D.s earned, and followed 4 years of decline.

U.S. citizens of Asian background, despite their sharp increases in graduate enrollments, earned only 3 percent of the S/E Ph.D.s awarded to U.S. citizens in 1988.

SUPPORT FOR S/E GRADUATE STUDENTS[28]

How do graduate S/E students pay for their educations? Since education is a crucial investment in developing the human talent needed for the Nation's science and engineering activities, the Federal Government has traditionally been a key source of support for graduate S/E study. Institutions, too—using funds in their general institutional budgets—provide support to graduate S/E students in order to attract and retain talented students. Changes in support patterns among mechanisms of student support, and in the different Federal agencies that provide the most graduate S/E student support, are discussed in the following paragraphs.

Sources of Graduate Student Support

One source of information on support of graduate S/E students is an annual survey of graduate S/E departments that requests the "primary" source of support for each full-time student.[29] Four broad categories describe the sources of support for graduate S/E students:

- Federal sources;
- Institutional sources, i.e., funds from schools' general budgets;
- Other sources, i.e., from sources outside the institution other than the Federal Government or the student; and
- Self-support, including the student's own tuition and fees paid.

Institutional sources of support have grown most rapidly throughout the 1980s, averaging nearly 4 percent yearly. In contrast, total enrollment has grown at a rate of around 2 percent per year over the same period. (See appendix table 2-16.) Increased institutional support for S/E graduate students has been particularly important in engineering and the social sciences. For instance, in the social science subfields, expanding institutional support has compensated for a decline in Federal support in these subfields over the decade.

Federal sources of graduate S/E support declined during the first part of the 1980s but turned strongly upward by mid-decade. (See figure 2-10.) In contrast, self-support and other outside sources of support slowed their increases.

Federal support of graduate S/E study between 1984 and 1988 grew most notably among students in computer

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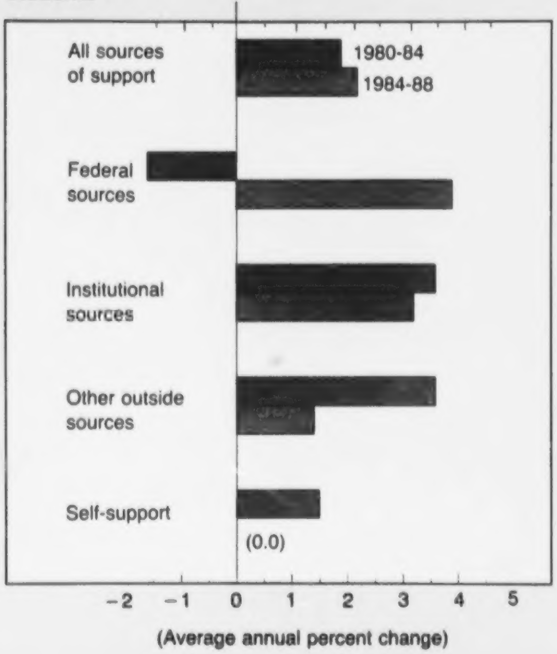
[28] This section discusses only full-time students in doctorate-granting institutions.

[29] NSF (1989a). Since students often attend graduate school with a package of financial aid from different sources and of different types, many sources are not reported. Consequently, virtually all support sources are underreported. In addition, no data on the *amount* of support provided are captured by this survey.

Figure 2-10.
Change in sources of support of S/E graduate students



Note: Includes full-time S/E graduate students in doctorate-granting institutions.
See appendix table 2-16. *Science & Engineering Indicators—1989*

science (15 percent annually) and the mathematical sciences (11 percent). Federal sources of support for graduate students in the environmental and social sciences declined throughout the decade. (See appendix table 2-16.)

The net result of these differing growth rates among sources of support for S/E graduate students was a different "mix" of support sources in 1988 versus 1980. By 1988, about 27 percent of S/E students overall reported "self-support" as their main support versus 30 percent in 1980; about 44 percent listed "institutional" support in 1988 versus about 40 percent in 1980; and about 20 percent noted "Federal" sources versus 22 percent in 1980.

Mechanisms of Student Support

Students receive financial assistance for graduate study in the sciences and engineering via five broad mechanisms.[30]

- *Fellowships* are usually awarded through a competition directly to the student by a source other than the institution.
- A *traineeship* is also competitive, but is awarded by the institution.
- *Assistantships* can be either for research or teaching, depending upon how the student's time under the grant is to be spent.
- *"Other"* types of support include Federal student loans and tuitions paid by the Department of Defense (DOD).
- *Self-support* covers student sources including parental support and privately arranged loans.

During the 1980s, the total number of fellowships and traineeships changed hardly at all, in contrast with growth in research assistantships that averaged nearly 5 percent per year. (See appendix table 2-17.) These trends, however, have not been equally distributed among the broad fields. Fellowships and traineeships combined have increased in engineering and the mathematical, computer, biological, and physical sciences. They became less common in all other fields.

Research assistantships have declined only in the agricultural sciences. Fields experiencing considerable growth in the number of S/E students reporting their main source of support as research assistantships include computer science (14 percent annually), engineering (7 percent), and the mathematical sciences (5 percent).

Teaching assistantships increased mostly in the mathematical sciences (4 percent) and engineering (5 percent) since 1980.

Federal Support Patterns

As noted above, Federal sources as a percentage of all sources of support declined between 1980 and 1988. However, the *number* of students reporting Federal sources as their primary support increased by about 4,000 students over the decade. During this period, both the mechanisms of Federal support for graduate students and the relative importance of the various Federal agencies in providing this support have changed.

Federally financed traineeships and fellowships have generally declined as a percentage of all Federal support mechanisms since 1980, but the number of research assistantships funded by Federal sources has increased sufficiently to more than offset the declines.[31] (See figure 2-11.) Research assistantships increased among the mechanisms

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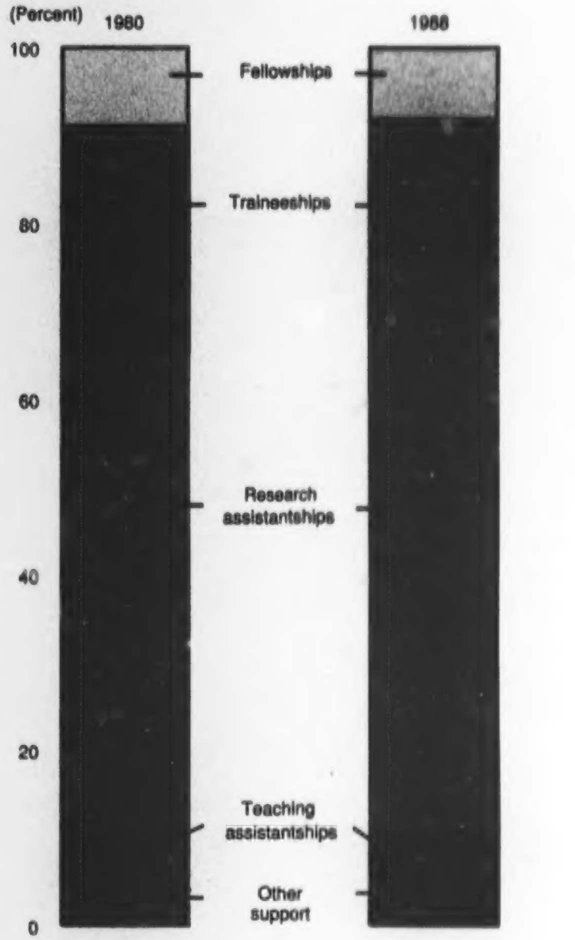
[30] For precise definitions, see NSF (1987a).

[31] For a detailed statistical study of federally financed research assistantships in science and engineering, see Snyder (1988). Among Snyder's conclusions were:

- "There appears to be a strong relationship between the presence and concentration of federally supported graduate research assistants (RAs) in a department and a variety of measures commonly associated with departmental quality.
- "There are significant differences in the utilization of RAs on research grants (RAs per $ million) by field, with Chemistry having almost 3x the utilization rate as the Biological Sciences.
- "There was a small overall shift in the concentration of federal RA support away from the highest rated (top 10 percent) departments to lesser rated quality departments.
- "The presence of federal RAs appears to have a positive impact on certain outcome measures of graduate education."

Figure 2-11.
Federal support of S/E graduate students, by type of support: 1980 and 1988



See appendix table 2-18. *Science & Engineering Indicators—1989*

of Federal support, rising from 55 percent in 1980 to 66 percent in 1988.

DOD, concomitant with its increased research and development (R&D) funding during the period (see chapter 4), supported 2,900 research assistantships in 1980 and 5,900 in 1988. (See appendix table 2-18.) The National Science Foundation (NSF), which supports the lion's share of research fellowships among the Federal agencies, increased its fellowship programs by about 2 percent per year, from 1,300 to 1,600. The Department of Health and Human Services, which includes the National Institutes of Health (NIH), funded fewer fellowships and traineeships in 1988 than in 1980, despite recent small increases by NIH.

In summary, the growth of federally funded R&D seems to have had the greatest impact on Federal support for graduate S/E students through the proliferation of research assistantships built into Federal R&D grants. Despite recent new NSF programs and slight increases by DOD, federally funded fellowships have not noticeably affected overall Federal support patterns in S/E higher education.

HIGHER EDUCATION S/E FACULTIES

Four-year colleges and universities employ more doctoral scientists and engineers each year. But since recent hiring rates have not kept pace with those of the 1950s and 1960s, these scientists and engineers are relatively older—and hold higher ranks—than a decade ago. Moreover, in recent years, increasing proportions of scientists and engineers in academic settings report greater amounts of work in research and development, suggesting a growing "research intensiveness" of U.S. college and university campuses. There are, however, differences among broad S/E fields for each of these general trends, as discussed in the following paragraphs.

Overall Employment Trends

U.S. colleges and universities[32] employed approximately 186,000 doctoral scientists in 1987—or 53 percent of the total doctoral scientists employed in the U.S.—and 24,000 doctoral engineers, or 35 percent of the Nation's employed doctoral engineers. (See appendix table 2-19.) The number of doctoral engineers on U.S. campuses has increased at twice the rate of doctoral scientists: 10 percent per year versus 5 percent per year, on the average, since 1981.

Patterns of Academic Employment

The percentage of academic doctoral scientists and engineers who report teaching as either their primary or secondary work activity has not changed considerably over the years. (See appendix tables 2-20 and 2-21.) However, some fields have considerably more doctoral staff on campus who perform research or other tasks to the exclusion of teaching. Up to 90 percent of mathematical Ph.D.s, for example, report teaching as a major work activity; in contrast, in the life sciences, only 60 percent to 65 percent have teaching duties. Computer science and the physical sciences also have relatively large proportions of Ph.D.s on campus who do not teach.

A growing research intensiveness of the Nation's campuses is further suggested in appendix table 2-20. Between 1981 and 1987, across nearly all fields, increasing proportions of academic doctoral scientists and engineers identified research and development as their primary work activity, while declining proportions identified teaching as their primary work activity. This general trend seems stronger in engineering than in the sciences: among doctoral engineers, the percentage reporting R&D as their primary activity rose from 23 percent in 1981 to 33 percent in 1987; corresponding growth among scientists was from 29 percent to 35 percent.

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[32] The discussion throughout this section refers only to employment at 4-year colleges and universities.

Text table 2-3. Academic doctoral scientists and engineers, by age and field

	Percentage under 40					Percentage 50 or older				
	1977	1981	1983	1985	1987	1977	1981	1983	1985	1987
All scientists and engineers	45	38	33	32	29	26	30	32	32	34
Scientists	45	39	34	32	29	26	29	32	32	33
Physical scientists	46	34	27	28	25	24	32	34	35	39
Mathematical scientists	53	38	30	28	29	19	24	27	32	32
Computer scientists	57	48	48	41	31	15	20	20	19	21
Environmental scientists	45	36	37	32	30	24	26	31	33	33
Life scientists	45	42	37	35	33	27	28	30	30	31
Psychologists	47	45	39	38	31	25	28	30	30	33
Social scientists	40	35	31	28	25	30	34	35	34	34
All engineers	38	29	28	30	27	26	34	34	37	41

See appendix table 2-19.

Science & Engineering Indicators—1989

Most of the increase in R&D has been focused on applied, rather than basic, research. In both science and engineering, doctoral employees report more work in applied and relatively less work in basic research. (See appendix table 2-20.) Moreover, since 1981, the number of academically employed doctoral scientists and engineers who report basic research as their primary activity has grown by 28 percent, compared with a 75-percent growth in reports of applied research.

Only the mathematical and computer sciences go against these general trends, however. In the mathematical sciences, the increasing percentage of doctoral scientists reporting R&D clearly emphasizes basic over applied research (81 percent in 1981 to 89 percent in 1987, versus 16 percent to 11 percent, respectively). In computer science, the recent high rates of growth in total employment in colleges and universities have left the percentage of total employment engaged primarily in either teaching or research virtually unchanged. Also, the percentages reporting either basic or applied research as a primary activity both increased at the expense of those researchers who reported development work in earlier surveys. (See appendix table 2-20.)

Academic Rank and Age

Engineering and most broad science fields have experienced increases in senior faculty ranks since 1981.[33] In engineering, the percentage of the professoriate holding the rank of full professor has grown to 55 percent in 1987, an average annual rate of growth of 5 percent since 1981. (See appendix table 2-21.) Among the sciences, the physical and mathematical sciences stand out with high percentages of faculty who are full professors: 58 percent and 50 percent, respectively. Concomitantly, the ranks of assistant professors have decreased in these fields; the use of instructors has decreased in all fields.

As a relatively new discipline, computer science has retained an anomalous position in the face of these general trends.[34] Compared with all other broad fields, computer science has more faculty with lower rank—e.g., 38 percent associate professors and 29 percent assistant professors versus 28 percent and 19 percent, respectively, in all S/E fields combined.

On average, academically employed doctoral engineers and scientists were older in 1987 than in 1977. (See text table 2-3.) In all fields, decreasing percentages were under 40 years of age in 1987 than in 1977, and increasing proportions were over 50. In engineering, a recent upturn in the proportions under 30 may have ended in 1987. (See appendix table 2-19.) Finally, in all fields, the proportions of doctorates employed in colleges and universities who are over 60 years of age increased considerably since 1977, and more than doubled (for example) in engineering and computer science.[35]

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[33] This and the next paragraph discuss only academic doctoral scientists and engineers who teach—i.e., "the professoriate"—as opposed to the total academic doctoral S/E employment discussed in the preceding paragraphs.

[34] NSB (1987), p. 49.

[35] For a discussion of possible future faculty shortages, see Lozier and Dooris (1987). In El-Khawas (1988), campus administrators reported shortages of faculty in computer science and an inability to fill vacancies in mathematics.

REFERENCES

American Association of Engineering Societies, Engineering Manpower Commission. 1989. *Engineering & Technology Enrollments Fall 1988*. Parts I and II. Washington, DC: American Association of Engineering Societies.

American Institute of Physics (AIP). 1988. "1986-87 Survey of Physics and Astronomy Bachelor's Degree Recipients." *AIP Report*. AIP Pub. No. R-211.19.

Aslanian, C.B., and H.M. Brickell. 1988. *How Americans in Transition Study for College Credit*. New York: College Entrance Examination Board.

Carnegie Council on Policy Studies in Higher Education. 1976. *A Classification of Institutions of Higher Education*. Berkeley: Carnegie Council on Policy Studies in Higher Education.

Carnegie Foundation for the Advancement of Teaching. 1987. *A Classification of Institutions of Higher Education*. Princeton: Carnegie Foundation for the Advancement of Teaching.

Carpenter, J. 1987. *Trends in Bachelors and Higher Degrees, 1975-1985*. Washington, DC: National Center for Education Statistics, U.S. Department of Education.

El-Khawas, E. 1988. *Campus Trends, 1988*. Washington, DC: American Council on Education.

Ellis, R.A. 1988. "Engineering and Engineering Technology Enrollments, 1988." *Engineering Education* 78, no. 9: 51-61.

Lane, M.J. 1988. "The Current Status of Women and Minorities in Engineering and Science." *Engineering Education* 78, no. 8: 750-55.

Lozier, G.G., and M.J. Dooris. 1987. "Is Higher Education Confronting Faculty Shortages?" University Park, PA: Office of Planning and Analysis, The Pennsylvania State University.

National Merit Scholarship Corporation. 1982-88. *Annual Report*. Ongoing annual series. Evanston, IL: National Merit Scholarship Corporation.

National Research Council (NRC). 1988a. *Summary Report 1987. Doctorate Recipients From United States Universities*. Washington, DC: National Academy Press.

____. 1988b. *Foreign and Foreign-Born Engineers in the United States*. Washington, DC: National Academy Press.

National Science Board (NSB). 1987. *Science & Engineering Indicators—1987*. NSB 87-1. Washington, DC: Government Printing Office.

____. 1985. *Science Indicators/The 1985 Report*. NSB 85-1. Washington, DC: Government Printing Office.

____. 1977. *Science Indicators—1976*. NSB 77-1. Washington, DC: Government Printing Office.

National Science Foundation (NSF). 1990. *Women and Minorities in Science and Engineering*. NSF 90-301. Washington, DC: NSF.

____. 1989a. *Academic Science/Engineering: Graduate Enrollment and Support, Fall 1987*. NSF 89-315. Washington, DC: NSF.

____. 1989b. *Science and Engineering Doctorates: 1960-88*. NSF 89-320. Washington, DC: NSF.

____. 1987a. *A Guide to NSF Science/Engineering Resources Data*. NSF 87-308. Washington, DC: NSF.

____. 1987b. "Education and the Professional Workforce." *Mosaic* 18, no. 1.

____. 1986. *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*. NSF 86-305 (revised). Washington, DC: NSF.

Snyder, R.G. 1988. *The Federal Research Assistantship: Indicators of Utilization in Graduate Research Training in Science and Engineering*. National Technical Information Service Accession Number PB89-222657/AS.

University of California at Los Angeles (UCLA), Cooperative Institutional Research Program. 1982-87. *The American Freshman: National Norms*. Ongoing annual series. Los Angeles: Graduate School of Education, UCLA.

____. 1987. *The American Freshman. Twenty Year Trends, 1966-1985*. Los Angeles: Graduate School of Education, UCLA.

U.S. Bureau of the Census. *Current Population Report*. Series P-20 On going annual series. Washington, DC: U.S. Bureau of the Census.

Chapter 3
Science and Engineering Workforce

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Science and Engineering Workforce

HIGHLIGHTS

- *Between 1980 and 1988, the number of those employed in science and engineering (S/E) jobs in private industry increased at a rate almost twice that for all workers.* Concurrently, the occupational and industrial mix of S/E employment experienced major changes. (See p. 63.)
- *Approximately 2.0 million scientists and 2.6 million engineers were employed in the S/E workforce in 1988.* Science employment nearly doubled since 1980, while employment of engineers increased by almost 75 percent. (See p. 66.)
- *Almost one-fourth of all scientists and one-tenth of all engineers employed in the United States in 1988 were working in non-S/E activities.* Within science fields, social scientists and computer specialists were the most likely to report non-S/E employment, while mechanical and electrical/electronics engineers were the most probable among engineering subfields. (See p. 66.)
- *Women scientists and engineers represented about 13 percent of the S/E workforce in 1986, up from 11 percent in 1980.* As a proportion of the total workforce, however, only about 1 percent of all employed women were working in S/E jobs in 1986, compared to almost 6 percent of all employed men. (See p. 67.)
- *Blacks continued to be underrepresented in science and engineering in 1986, accounting for only 2.2 percent of the S/E workforce.* In contrast, Asians represented almost 6 percent of those employed in science and engineering, while native American scientists and engineers represented somewhat less than 1 percent of total S/E employment. (See pp. 67-68.)
- *At the doctoral level, scientists outnumbered engineers by about five to one in 1987 (351,000 versus 68,000).* Over the 1981-87 period, total employment growth for both scientists and engineers averaged nearly 5 percent per year. (See p. 68.)
- *The job market was favorable for scientists and engineers in most S/E fields in 1986.* Unemployment rates averaged 1.9 percent for scientists and 1.2 percent for engineers, compared to 2 percent and 7.2 percent, respectively, for all professional and technical workers and the total workforce. (See p. 73.)
- *Over the 1988-2000 period, the number of jobs for scientists and engineers in private industry is expected to increase by over 600,000, with three-fifths of these new jobs to be located in the services-producing sector.* The faster creation of S/E jobs in this sector continues the trend observed between 1980 and 1988. Overall, the proportion of industry S/E jobs in the services-producing sector is expected to increase from 43 percent in 1986 to 46 percent by the year 2000. (See p. 74.)
- *Between 1988 and 2000, the occupational composition of industry jobs is expected to change away from production and assembly-line jobs toward professional, managerial, and technical occupations.* Thus, while industry as a whole is expected to provide approximately 9 percent more jobs between 1986 and 2000, employment opportunities for S/E jobs are projected to increase by about 34 percent. (See pp. 76-77.)
- *The United States led the United Kingdom in the number of scientists per 1,000 total labor force (12 versus 8 per 1,000) and was second to Japan in the number of engineers per 1,000 labor force (18 versus 19 per 1,000) in the early 1980s.* (See p. 82.)

Over the next decade, several factors will combine to substantially affect the demand for and supply of scientists and engineers. On the demand side, two factors are worthy of consideration:

(1) *The need for workers* stemming from economic growth, changing technology, and competitive challenges; and

(2) *The need to replace workers* who leave the science and engineering (S/E) workforce due to death, retirement, transfer to other occupations, and emigration.

Of the two factors, the latter will translate into the larger demand. The increases needed in new S/E workers are expected to be at lower levels of growth than in the early and mid-1980s; however, employers will need larger numbers of replacements for attrition from the overall growing S/E labor force.

On the supply side exist concerns as to the impact on future levels of new S/E graduates of a declining college-age population. This diminishing population has already resulted in a falling rate of growth in S/E bachelor's degrees. Another factor affecting the future supply of new

S/E graduates is a change in the ethnic and gender mix of the college-age population. In the future, this population will have higher proportions of minorities and women (see figure 3-1)—groups that until now have had relatively low participation rates in S/E education.[1]

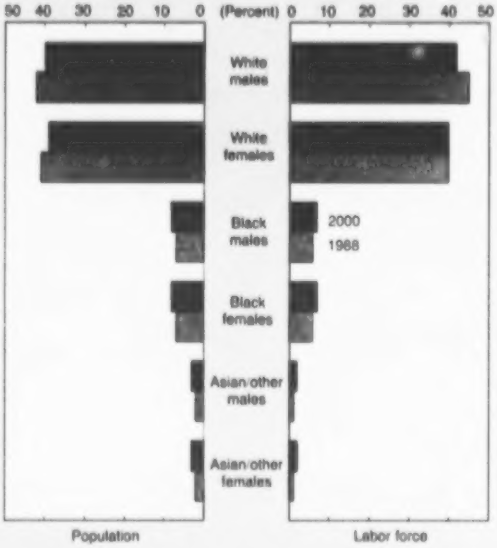
These and other diverse factors will together determine the future balance of the S/E labor market. This chapter closely examines past and projected growth of S/E jobs in the industrial sector, which forms the core of demand for S/E occupations (about two-thirds of total S/E employment). Information on S/E supply is also presented. For the first time, this includes a numerical illustration and detailed analysis of S/E personnel flows into and out of the workforce.

Finally, this chapter provides comparative data on international science and engineering employment.

INDUSTRIAL S/E JOB PATTERNS

Between 1980 and 1988, the number of those employed in S/E jobs in private industry[2] increased at a rate almost twice that for all workers. (See figure O-8.) Concurrently, the occupational and industrial mix of S/E employment experienced major changes. For example, overall employment in the services-producing industries—which benefitted from substantial economic growth—increased by 29 percent. The corresponding increase in S/E employment in the sector was even greater: 57 percent. (See figure 3-2.) This increase, however, has stemmed less from growth within the sector than from an increased share of declining total manufacturing jobs.

Figure 3-1.
Distribution of 20- to 24-year-old population and labor force by gender and race: 1988 and projected 2000



SOURCE: Projections of the U.S. by age, sex, and race, 1988–2080, *Current Population Reports*, U.S. Department of Commerce; and *Projections 2000*, Bureau of Labor Statistics, U.S. Department of Labor, March 1988.

Science & Engineering Indicators—1989

Services-Producing Industries

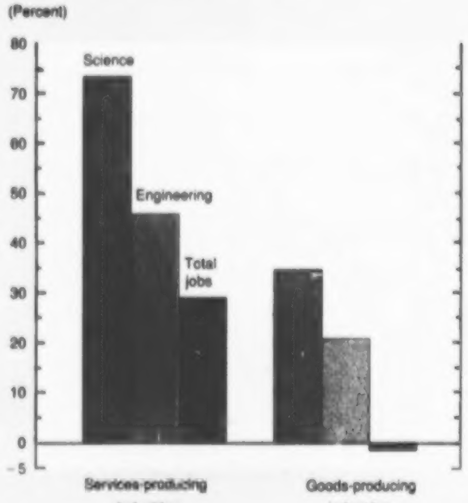
The services-producing industries are divided into four major divisions:

- Communications, utilities, and transportation;
- Trade;
- Financial services; and
- Business and related services.

Together, these industries provided jobs for approximately 446,000 engineers and 359,000 scientists in 1988, up from 306,000 and 207,000 (respectively) in 1980.

Over the 1980-88 period, the concentration of total S/E jobs in the private sector gradually shifted from goods-producing industries to services-producing industries. In fact, the proportion in the latter sector increased from 38 percent in 1980 to an estimated 43 percent in 1988.[3] This increase can be attributed to (1) a faster rate of employment growth for S/E personnel in services-producing industries, and (2) the sector's overall economic and employment growth. Total employment in services-producing

Figure 3-2.
Increase in science, engineering, and total jobs in private industry, by sector: 1980-88



See appendix table 3-1. *Science & Engineering Indicators—1989*

industries grew at an average annual rate of 3.2 percent between 1980 and 1988; the number of S/E jobs increased on average by 5.8 percent. The proportion of the services-producing workforce in S/E positions rose during this time from 1.3 percent of total employment in 1980 to an estimated 1.6 percent in 1988.

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[1] NSF (1988a), p. 29.

[2] The 1980-88 data on personnel employed in private industry S/E jobs in this section are from the U.S. Bureau of Labor Statistics Occupational Employment Statistics surveys. These surveys are of establishments and reflect employers' staffing patterns.

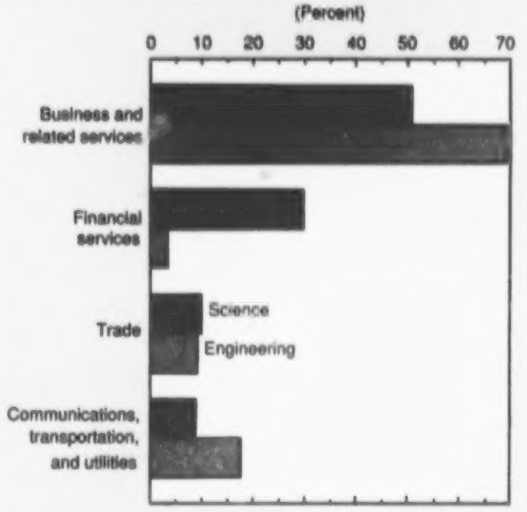
[3] NSF (1988b), p. 2.

Business and Related Services. This was the largest and second fastest growing division of the services-producing sector over the 1980-88 period. The major employers of S/E workers in this division were involved in computer and data processing services, engineering and architectural services, and independent research and development (R&D). There were 310,000 engineering jobs and 183,000 scientist positions in this division in 1988, accounting for 70 percent and 51 percent, respectively, of the services-producing sector's engineering and science jobs in 1988. (See figure 3-3.) During the 1980-88 period, the number of jobs for engineers increased at an average rate of 7.1 percent per year, slightly higher than the 5.3-percent annual rate for scientists. (See figure 3-4.)

Several factors influenced the S/E job growth in business and related services. First, the revolution in information technologies and strong demand for information/data services created increasing employment opportunities for S/E workers in computer and data processing services. Also, new methods of delivering information-related services led to the development of major growth segments in this industry. For example, the extensive use of local area networks and electronic data interchange networks developed mostly over the past 5 years.

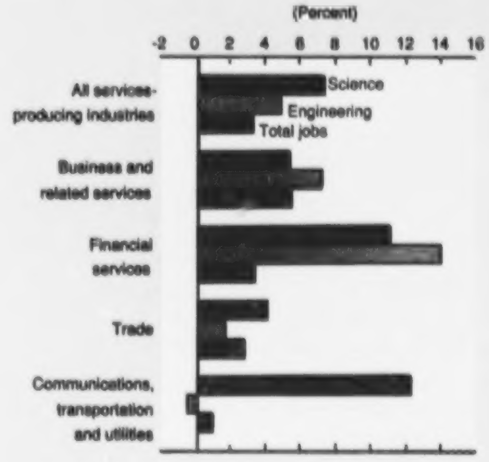
Financial Services. The most rapid S/E job growth in the services-producing sector occurred in the financial services division (i.e., firms engaged in banking, credit, insurance, and real estate). Increasing use of technological advances and computerized services resulted in greater requirements for computer specialists and mathematical and social scientists. Between 1980 and 1988, jobs for these workers rose at an average annual rate of 11 percent; further, workers in these fields accounted for approximately 90 percent of this division's 122,000 S/E jobs in 1988.

Figure 3-3.
Distribution of science and engineering jobs in services-producing industries: 1988



See appendix table 3-1. *Science & Engineering Indicators—1989*

Figure 3-4.
Annual rates of growth for science, engineering, and total jobs in services-producing industries: 1980-88



See appendix table 3-1. *Science & Engineering Indicators—1989*

Factors Behind Growth in Service Industries. The recent growth of service industries and their S/E employment is not simply due to a transfer of jobs to them by goods-producing industries as these latter contract out activities formerly performed in-house. Such transference is not a major factor, since both the numbers and share of total employment in technical occupations within the goods-producing sector are increasing. Also, according to a recent study by the U.S. Bureau of Labor Statistics (BLS), the transfer of work formerly done in-house by manufacturers accounted for—at best—only a small fraction of the growth in the services-producing sector.

Rather, the growth in industries serving producers has been primarily attributed to increases in the supply of new services.[4] The continued development of new services should keep demand growing for the outputs of these industries even as scientific and technical employment in the goods-producing industries that they service continues its upward growth.

Goods-Producing Industries

The goods-producing industries fall into the major divisions of:

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[4] Tschetter (1987).

- Durable goods manufacturing,
- Nondurable goods manufacturing,
- Mining, and
- Construction.

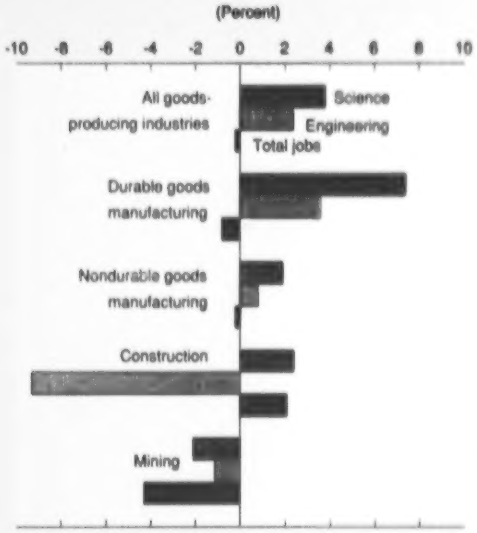
Together, these divisions provided jobs for 830,000 engineers and 225,000 scientists in 1988, compared to 686,000 and 167,000—respectively—in 1980.

S/E jobs in goods-producing industries expanded at an average rate of 2.7 percent per year between 1980 and 1988. (See figure 3-5.) Unlike the services-producing industries, total employment in this sector experienced no growth over this period: a small increase in total employment growth in construction was offset by declines in the mining and both manufacturing divisions. S/E job growth in the manufacturing divisions was maintained for several reasons, including increases in:

- Defense spending,
- Technological competition,
- Pressure to improve productivity,
- High-technology capital investment, and
- R&D expenditures.

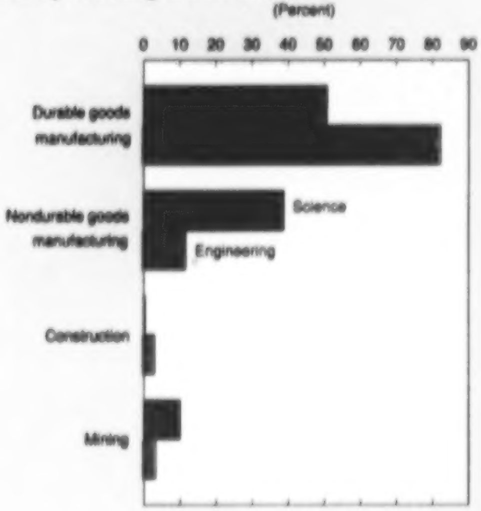
Durable goods manufacturing was the largest provider of S/E jobs in the goods-producing sector; in 1988, over 80 percent of the sector's engineering jobs, and 51 percent of its science jobs, were in this division. (See figure 3-6.) Major S/E employers within this division in 1988 were:

Figure 3-5.
Annual rates of growth for science, engineering, and total jobs in goods-producing industries: 1980-88



See appendix table 3-1. *Science & Engineering Indicators—1989*

Figure 3-6.
Distribution of science and engineering jobs in goods-producing industries: 1988



See appendix table 3-1. *Science & Engineering Indicators—1989*

- Aerospace industries (manufacturers of aircraft and parts, space vehicles, and guided missiles) with 24 percent of the division's S/E jobs;
- Makers of communication equipment, 15 percent;
- Office and computing equipment manufacturers, 12 percent; and
- Electronic components industries, 12 percent.

Occupations

While industry as a whole was providing increasingly greater employment opportunities in almost all S/E occupational categories between 1980 and 1988, services-producing industries remained the primary source of employment for most scientists (most notably computer specialists and social scientists), while engineers continued to find more job opportunities in the goods-producing sector. The proportion of scientists employed in services-producing industries rose in every major category between 1980 and 1988. The share of most engineering subfields in the goods-producing sector increased a small amount over the period. The goods-producing and services-producing sectors showed similar occupational patterns of S/E employment in 1988.

UTILIZATION OF S/E PERSONNEL

Employment Levels and Demographic Trends

In 1988, approximately 5.9 million persons in the United States were—by virtue of their education and work experience—considered scientists (2.8 million) or engineers

(3.1 million).[5] Only 72 percent of these scientists (2.0 million) and 85 percent of these engineers (2.6 million) were in the S/E workforce, however. The remaining scientists and engineers were either employed in non-S/E jobs, unemployed and seeking employment, or outside the labor force.

Scientists and engineers employed in non-S/E jobs are not necessarily underutilized, however, since their S/E training and education may be prerequisites for—or provide valuable inputs to—their work. Of those scientists who reported non-S/E employment in 1988, almost one-third (208,000) were social scientists, and approximately one-fourth (158,000) were computer specialists. (See figure 3-7.) Among engineers employed in non-S/E activities at that time, one-fifth (51,000) were mechanical engineers and another 17 percent were electrical/electronics engineers.

Overall S/E Employment Growth and Concentration.[6] Employment growth of scientists in the S/E workforce varied from that of engineers during the 1980-88 period. Science employment nearly doubled during this time; employment of engineers increased by almost 75 percent. (See

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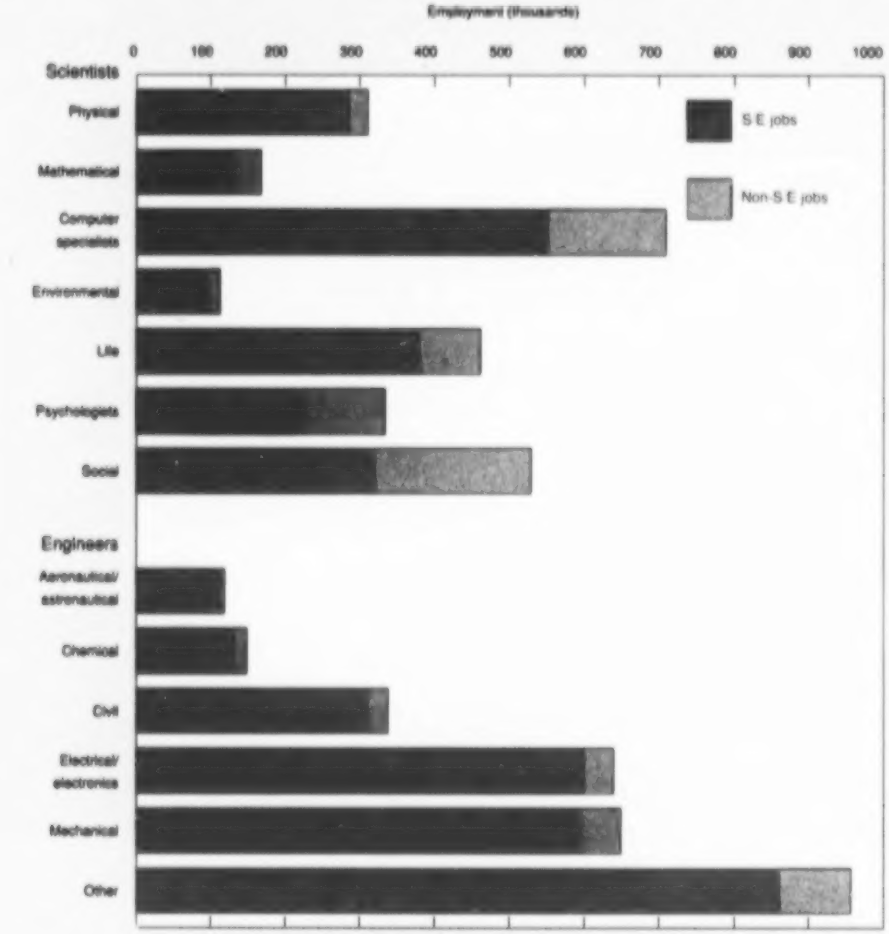
[5] Broadly speaking, a person is considered a scientist or engineer if he or she meets at least two of the following criteria:

- Has earned a degree in science (including social science) or engineering,
- Has been employed in an S/E occupation, and/or
- Has professionally identified himself or herself as a scientist or engineer on the basis of total education and work experience.

[6] S/E employment includes only those scientists and engineers employed in science and engineering jobs, unless otherwise indicated. Technician and other occupational groups that may be engaged in S/E-type work are not included.

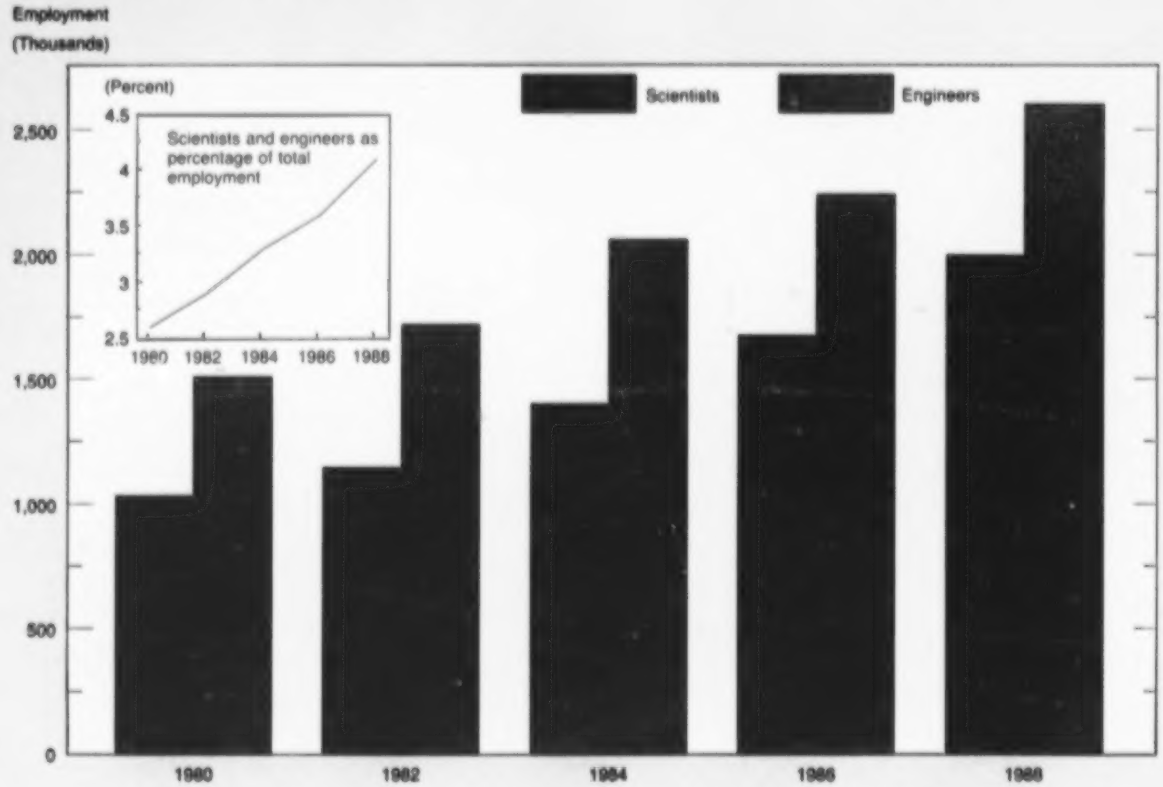
Figure 3-7.
Employment status of scientists and engineers, by field: 1988



See appendix tables 3-2 and 3-3.

Science & Engineering Indicators—1989

Figure 3-8.
Scientists and engineers employed in S/E jobs: 1980-88



See appendix tables 3-2 and 3-8.

Science & Engineering Indicators—1989

figure O-9 in Overview.) Overall, the S/E workforce grew by 7.8 percent per year during this period. In comparison, total U.S. employment increased by only 1.8 percent per year.[7] Consequently, the proportion of the workforce employed in science and engineering grew from 2.6 percent in 1980 to 4.1 percent in 1988. (See figure 3-8.) In addition, real gross national product (GNP)—an indicator of overall economic activity—increased at an annual rate of only 3.0 percent over the period.[8]

Almost half of both scientists and engineers in the S/E workforce were concentrated in either of two fields in 1988. Among scientists, 47 percent were employed as either computer specialists or life scientists; for engineers, 46 percent were either electrical/electronics or mechanical engineers.

Employment of Women and Minorities. Approximately 13 percent of the S/E workforce were women in 1986, up from 11 percent in 1980. As a proportion of the total workforce, however, only about 1 percent of all employed women were working in S/E jobs in 1986, compared to almost 6 percent of all employed men.[9] Women accounted for a much larger share of employment in the science workforce than in engineering. While almost 26 percent of scientists in the S/E workforce were women in 1986, only 4 percent of engineers were female. (See figure O-10 in Overview.) Among scientists, women represented 42 percent of all psychologists in 1986, but only about 13 percent of the physical and environmental scientists. In engineering, women accounted for between 3 percent of both mechanical and electrical/electronics engineers and almost 8 percent of chemical engineers.

Blacks accounted for only 2.2 percent of those employed in S/E jobs in 1986. (See figure 3-9.) In the general workforce, they represented 10 percent of total U.S. employment and almost 7 percent of those employed in the professional and related workforce.[10] In contrast, Asians represented less than 2 percent of the U.S. labor force and only 3 percent of those in professional fields,[11] but almost

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[7] Council of Economic Advisers (1989), p. 347.

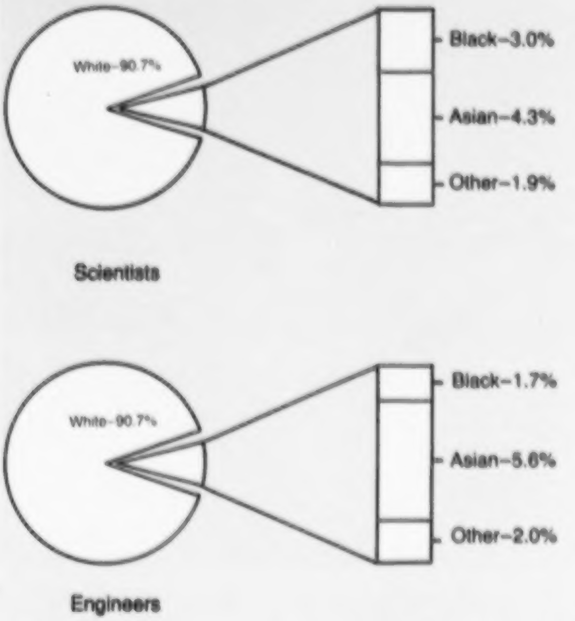
[8] Ibid., p. 310.

[9] U.S. BLS (1987b), p. 8.

[10] U.S. BLS (1987a), p. 179.

[11] U.S. Bureau of the Census (1983).

Figure 3-9.
Distribution of scientists and engineers employed in S/E jobs, by race: 1986



See appendix table 3-4. *Science & Engineering Indicators—1989*

6 percent of all scientists and engineers. Native American scientists and engineers represented somewhat less than 1 percent of total S/E employment; this was roughly similar to their participation in the overall U.S. labor force.[12, 13]

Approximately 2.1 percent of the scientists and engineers in the S/E workforce in 1986 were Hispanic.[14] Roughly 6.6 percent of all employed persons were of Hispanic origin, as were 3.3 percent of those in professional and related occupations.[15]

Doctoral Scientists and Engineers

Employment of those holding science and engineering doctorates reached 419,000 in 1987, an increase of 22 percent since 1981.[16] The employment growth of S/E doctorate-holders between 1981 and 1987 slowed from that of prior years, increasing by 3.3 percent per year versus 4.8 percent per year between 1977 and 1981.

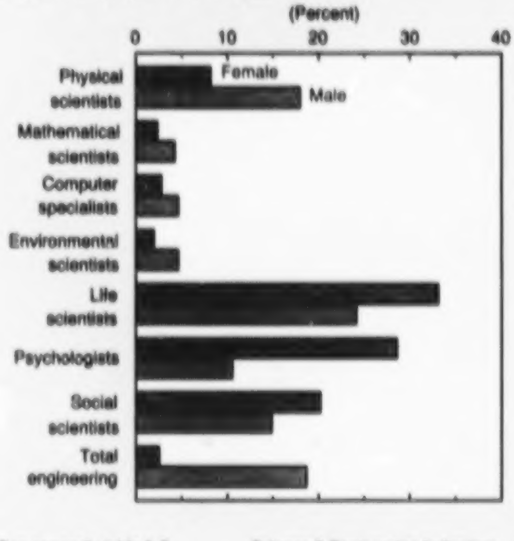
Because scientists are more highly concentrated than engineers in academia, where higher levels of education are required for professional status, there is a higher proportion of science doctorate-holders. In fact, scientists at the doctoral level outnumbered engineers by about five to one in 1987 (351,000 versus 68,000); this ratio was virtually unchanged during the 1980s.

In 1987, doctoral women and men scientists and engineers were employed in different fields. A higher proportion of Ph.D. women (97 percent) than men (81 percent) were scientists; over four-fifths of these women were in either the life sciences, psychology, or the social sciences. (See figure 3-10.) Ph.D. men, in contrast, were concentrated in either the life or physical sciences. Within engineering, women doctorate-holders were more likely to be concentrated in either electrical/electronics or materials engineering; men were most likely to be employed in electrical/electronics engineering.

Blacks constituted only about 1.5 percent (6,400) of all employed doctoral scientists and engineers in 1987: this was a slight (1.3 percent) increase over 1981. The almost 37,000 employed Asians in 1987 represented about 9 percent of the total, up slightly from 8 percent in 1981. (See figure 3-11.)

Hispanic Ph.D. scientists and engineers represented 1.6 percent of all doctoral scientists and engineers in 1987, up from 1.4 percent in 1981. Among doctorate-holders, Hispanics were slightly more likely than all Ph.D.s to be scientists rather than engineers.

Figure 3-10.
Distribution of employed doctoral scientists and engineers, by field and gender: 1987



See appendix table 3-5. *Science & Engineering Indicators—1989*

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[12] Ibid.

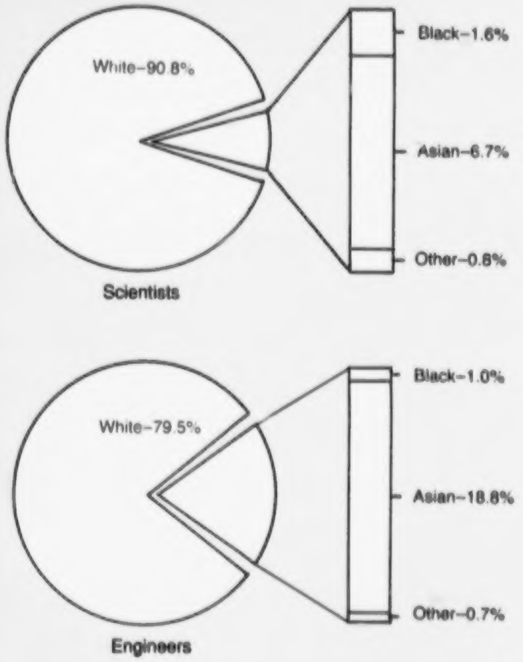
[13] Data for native Americans should be viewed with caution, however, since the estimates for both scientists and engineers and for the overall U.S. labor force are based on an individual's own classification as to his or her native American heritage; such perceptions may change over time.

[14] Hispanics are a diverse ethnic group, and it would be desirable to distinguish among Mexican Americans, Puerto Ricans, and other Hispanics, since their respective socioeconomic backgrounds and reasons for underrepresentation may differ. Because of data limitations, however, the present discussion on Hispanics treats them in aggregate.

[15] U.S. BLS (1987a), p. 179.

[16] This 419,000 includes 40,500 S/E doctorate-holders employed in non-S/E jobs. Detailed data comparable to that for all scientists and engineers employed in S/E jobs are not available.

Figure 3-11.
Distribution of employed doctoral scientists and engineers, by race: 1987



See appendix table 3-6.

Science & Engineering Indicators—1989

SUPPLY AND DEMAND FOR S/E PERSONNEL—LABOR MARKET INDICATORS

The demographic employment trends discussed above indicate that women and ethnic minorities have been steadily increasing their representation within a rapidly growing science and engineering workforce. These trends, however, do not indicate whether the S/E workforce has expanded sufficiently to keep pace with the needs of the economy. To help assess S/E labor market balance, and the extent to which the S/E workforce is utilizing women and minorities, several labor market indicators can be used. General measures of S/E supply and demand conditions include:

- Labor force participation rates,
- Unemployment rates,
- S/E employment rates,
- Experience of recent S/E graduates,
- Recent hiring experiences of S/E employers, and
- Trends in S/E recruitment.

While no single statistic can provide a firm basis for measuring shortages or surpluses of scientists and engineers, some statistics—when analyzed together—allow for meaningful inferences about the condition of the S/E labor market.

Labor Force Participation Rates

The S/E labor force includes scientists and engineers who are employed—either in or out of science and engineering—and those who are unemployed but seeking employment. The labor force is a measure of those who are economically active and thus directly available to carry out national efforts in science and technology. Labor force participation rates measure the fraction of the S/E population in the labor force. Low rates would suggest that many of those with S/E training and skills are not using these skills in S/E or other jobs.

In 1986, approximately 95 percent of the S/E population was in the labor force, with scientists and engineers equally likely to be working or seeking employment. This rate is higher than the 82-percent rate for the general population with 4 or more years of college.[17]

The difference in participation rates cannot be accounted for by differences in the gender composition of the S/E versus the general population. Stratification by gender shows that the participation rate for women in science and engineering was about equal to that for men (94 percent versus 95 percent), with little variation among S/E fields. In comparison, women and men in the general population who had completed 4 or more years of college had participation rates of 74 percent and 88 percent, respectively. Over the 1980-86 period, participation rates increased for women scientists and engineers, rising from 90 percent in 1980; rates remained stable for men.

Black scientists and engineers reported a labor force participation rate of 97 percent in 1986. This was slightly higher than the 96-percent rates for both Asians and native Americans; for whites, the rate was 94 percent. The S/E participation rate for blacks was much higher than that for blacks in the overall population (63 percent) or for black college graduates (87 percent). Since 1980, the labor force participation rate for black scientists and engineers has remained relatively stable; for Asians, the rate has declined from 98 percent in 1980.

Unemployment Rates

A standard measure of labor market conditions is the unemployment rate, which measures the proportion of those in the workforce who are not employed but seeking work. In the 1980s, scientists and engineers have been maintaining their labor market position, although they have been outperformed by both the general labor force and all professional and related workers. In 1980, the unemployment rates for scientists and engineers were 1.6

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[17] U.S. BLS (1987c).

percent and 1.0 percent, respectively, compared to 2.5 percent for all professional and technical workers and 7.1 percent for the entire U.S. workforce. In 1986, the rate for all professional and technical workers had fallen to 2.0 percent and the rate for the total workforce rose to 7.2 percent.[18] S/E unemployment increased slightly faster, rising to 1.9 percent for scientists and 1.2 percent for engineers in 1986.

Comparisons by gender show that the unemployment rate for women scientists and engineers was more than twice that for men in 1986: 2.7 percent versus 1.3 percent. (See figure 3-12.) The rate for S/E women was substantially lower than that for all women in the United States (7.1 percent), but similar to that for women in professional occupations (2.3 percent) and women college graduates (2.4 percent). Since 1980, unemployment rates for both women and men scientists and engineers have increased from 1.5 percent and 1.0 percent, respectively.

The unemployment rate for black scientists and engineers in 1986 averaged 3.8 percent; this rate was more than twice that for white scientists and engineers (1.5 percent) and Asians (1.8 percent), and more than three

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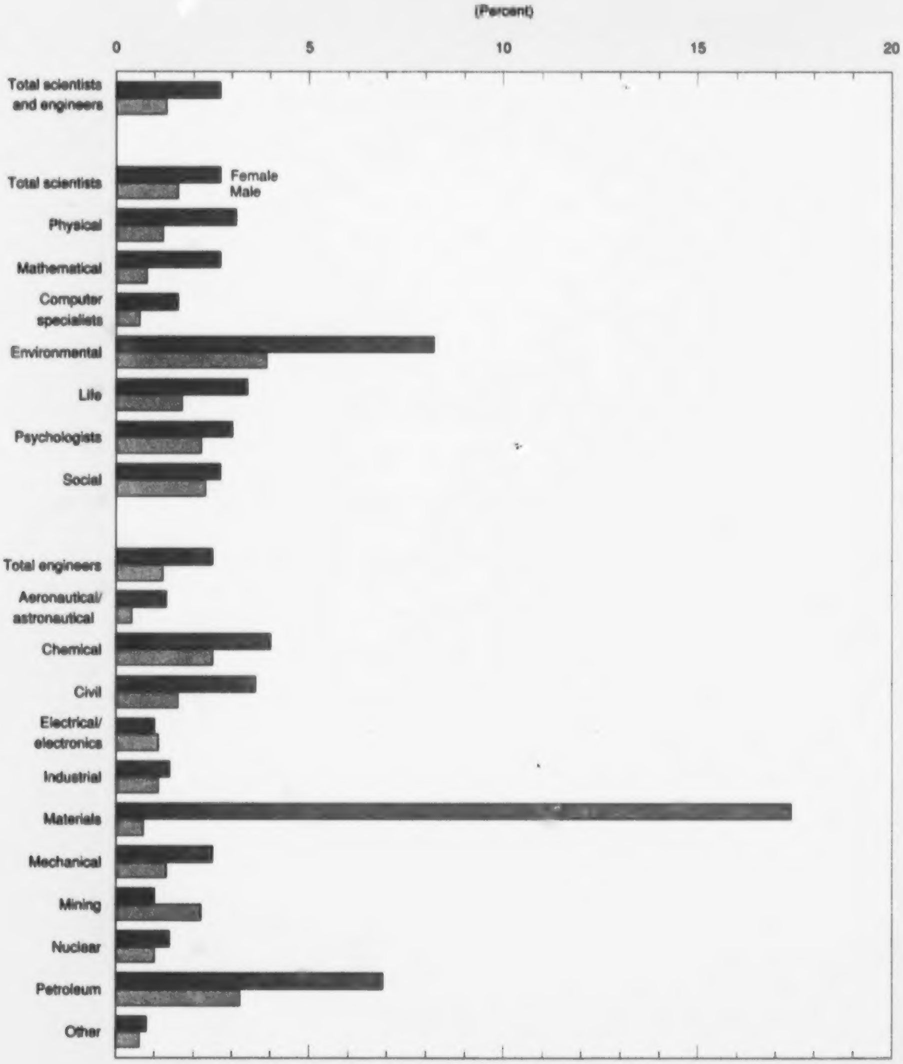
[18] U.S. BLS (1987a), p. 168.

Figure 3-12.
Unemployment rates of scientists and engineers, by field and gender: 1986



See appendix table 3-7.

Science & Engineering Indicators—1989

times higher than the rate for native Americans (1.2 percent).

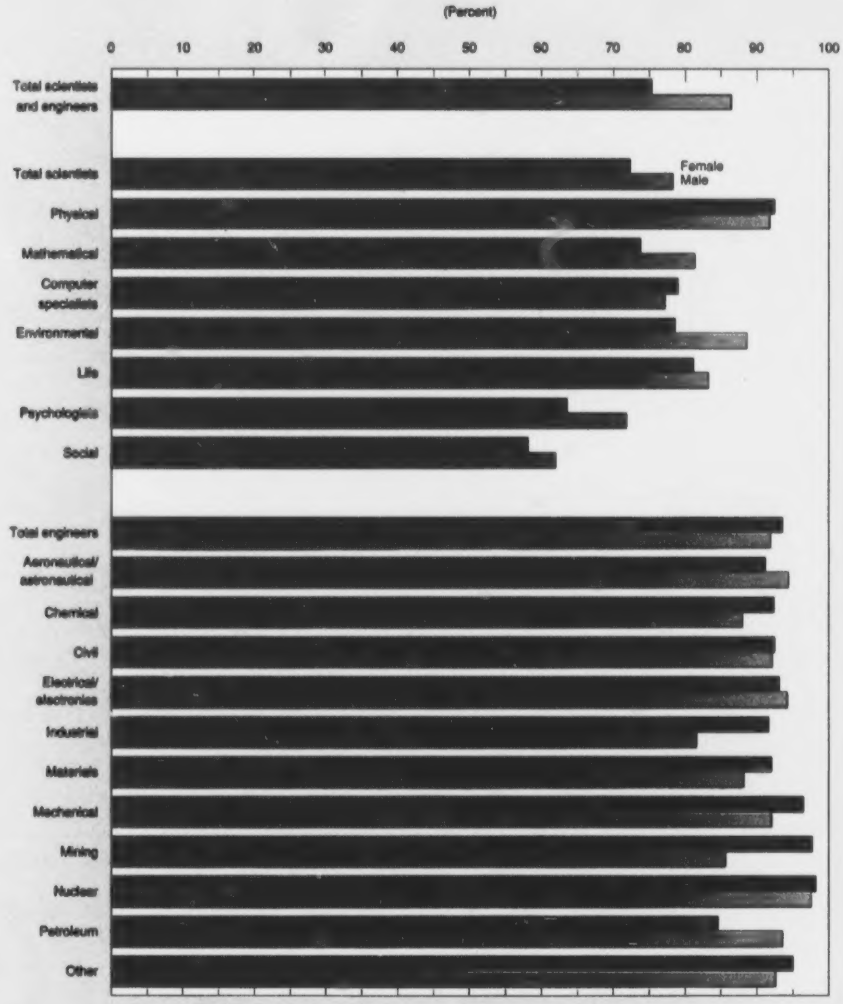
S/E Employment Rates

The S/E employment rate measures the extent to which employed scientists or engineers have an S/E job. Reasons for non-S/E employment include lack of available S/E jobs, higher pay for non-S/E employment, location, or preference for a job outside of science and engineering.

In 1986, the S/E employment rate was 85 percent (down from 89 percent in 1980); the rate for engineers (92 percent) was substantially above that for scientists (77 percent). (See figure 3-13.) Within science fields, the rates ranged from 61 percent in the social sciences and 78 percent in the computer specialties to 87 percent in the environmental and physical sciences.

Rates by Gender. Women scientists and engineers are less likely than men to work in science- or engineering-related activities. In 1986, the S/E employment rate for women was 75 percent; that for men was 80 percent. These rates have declined steadily for both women and men throughout the eighties: in 1980, the rates were 87 percent and 89 percent, respectively. The somewhat larger decline for women partially reflects their high concentrations in psychology and social science—fields in which S/E employ-

Figure 3-13.
Science and engineering employment rates, by field and gender: 1986



See appendix table 3-7.

Science & Engineering Indicators—1989

ment rates have fallen dramatically during the eighties for both women and men. More than one-third of women, compared with about one-tenth of men, were in one of these fields in 1986.

S/E employment rates for men and women vary by field, with the widest fluctuations occurring in the sciences. In 1986, the S/E employment rate for women scientists was 72 percent, compared with 78 percent for men. In engineering, however, the rate for women (94 percent) was above that for men.

Rates by Race. The S/E employment rate for black scientists and engineers was 77 percent in 1986, compared to 85 percent for whites and 88 percent for Asians. The higher rate for Asians in 1986 reflects the relatively large proportion of Asians who are engineers rather than scientists. On average, the S/E employment rate for Asian engineers was 95 percent in 1986, compared to 92 percent for whites and 90 percent for blacks. The S/E employment rate for black scientists was below that for whites and Asians across most major fields of science except mathematics: here the rate for blacks (90 percent) was above that for both whites (79 percent) and Asians (70 percent).

Experience of Recent S/E Graduates

The experience of recent S/E graduates is another indicator of the degree of market balance. In general, if the demand for scientists and engineers is greater than the supply at existing salary levels, the proportions of recent graduates who obtain jobs in science or engineering will be relatively high. Those proportions, however, vary considerably by field. This section presents data from a 1986 national survey of 1984 and 1985 bachelor's and master's degree recipients.

Unemployment Rates. In 1986, relatively few recent S/E graduates were unable to find employment; only 3.7 percent of the graduates with bachelor's degrees in science, and 2.4 percent of those with engineering degrees, reported that they were unemployed. For master's degree recipients, the rates were 2.6 percent for those with degrees in science and 1.2 percent for recipients of engineering degrees.

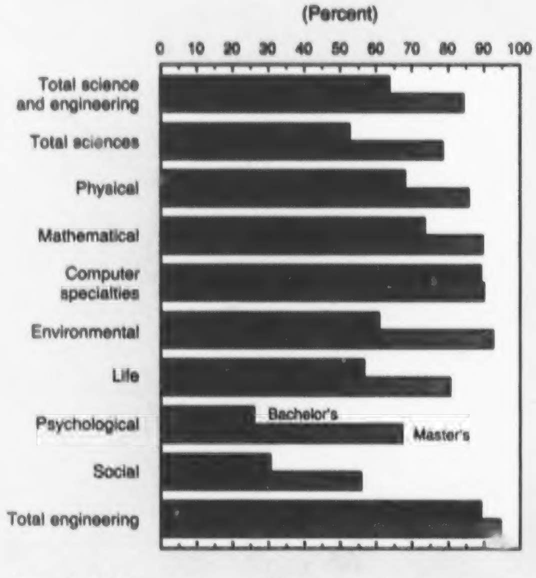
Unemployment rates were similar for men and women at the baccalaureate level; some differences began to arise at the master's degree level, however. For those who received their degrees in 1984 or 1985, unemployment rates for recent S/E bachelor's recipients were 3.4 percent (men) and 3.7 percent (women) in 1986. At this level, unemployment rates for women were below those for men in mathematics, the environmental sciences, psychology, and almost all engineering subfields. At the S/E master's degree level, the rate for women (3.2 percent) was almost twice that for men (1.7 percent). With little exception, women's unemployment rates were higher than men's across all fields.

S/E Employment Rates. S/E employment rates for recent S/E graduates with master's degrees were similar to those for more experienced scientists and engineers, while the rates for bachelor's degree recipients were lower.[19] The greater opportunities for employment in science and, to a lesser extent, engineering jobs for master's degree-holders may reflect the higher levels of investment in field-specific training; fewer S/E job openings at the bachelor's level may indicate entry-level job requirements for advanced degrees.

For both master's and bachelor's degree recipients, S/E employment rates varied between scientists and engineers. (See figure 3-14.) At the master's level, 79 percent of science graduates were working in S/E occupations, compared with 95 percent of engineering graduates. For most science fields, almost 90 percent of those with master's degrees were employed in S/E occupations; the life (81 percent) and social sciences (56 percent) were the exceptions. Although rates were lower for bachelor's degree recipients, the same general pattern prevailed. The average rate for engineers (89 percent) was substantially higher than that for scientists (53 percent); the lowest rate was recorded by social scientists (31 percent).

The S/E employment rates for men generally were higher than those for women at both the bachelor's and master's degree levels. The specific field concentrations of each gender contributed to some of the difference in these rates. For example, the low S/E employment rate in the social and behavioral sciences, coupled with the concentration of women in these fields, effectively lowered the average S/E employment rate for women. On the other hand, the high S/E employment rate in engineering—in which men were predominant—had the effect of raising men's average rate.

Figure 3-14.
Percentage of recent science and engineering degree recipients employed in S/E jobs: 1986



See appendix table 3-10. *Science & Engineering Indicators—1989*

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[19] NSF (1987), p. 89.

Mobility. Substantial field mobility can be identified at entry to the labor market, a characteristic resulting from supply/demand adjustments and flexibility of S/E personnel. In 1986, for example, 30 percent of the recent bachelor's and 23 percent of recent master's graduates working as computer specialists did not receive their degrees in the computer sciences. (See figure 3-15.) Rather, graduates in mathematics, engineering, and the social sciences—responding to the job opportunities in computer specialties—accounted for the majority of influx from other S/E fields.

Employer Shortages of S/E Personnel

Another direct indicator of S/E supply and demand imbalances in the S/E labor market is the reported experience of employers in meeting their staffing requirements. An NSF survey of the industrial S/E labor market, conducted in January 1989, found that nearly 46 percent of the establishments in major S/E-employing industries report a shortage in at least one field of science or engineering. While many establishments reported shortages, such positions were distributed across a variety of S/E fields and were not concentrated in a single discipline.

Science and engineering fields with the highest reported levels of shortages were:

- Electronics engineering—22 percent of employers reporting;
- Chemistry—21 percent;
- Electrical engineering, computer engineering, and computer science—20 percent each; and
- Chemical engineering—18 percent.

Across all fields, 80 percent of the employers of scientists, and 75 percent of the employers of engineers, reported plans to hire experienced personnel rather than new college graduates, indicating that the supply of new graduates is less of a problem.

The equilibrium between S/E supply and demand improved since the beginning of the 1980s, when at least one-half of the employers of most engineering and computer specialties subfields reported shortages.[20]

Engineering schools in the U.S. have reported what may be considered serious and persistent shortages of faculty. In 1986, almost 9 percent of authorized full-time engineering faculty positions were unfilled. Furthermore, many institutions reported that the authorized levels would be higher if it were possible to fill such positions.[21] Shortages of engineering faculty are grounded in the long-term decline in engineering doctorates awarded to U.S. citizens,[22] and the increasing demand for engineering Ph.D.-holders in the industrial sector.

High Technology Recruitment Index

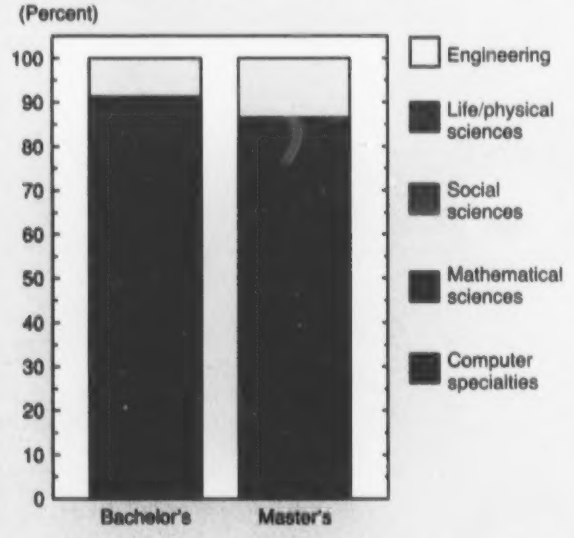
The Deutsch, Shea, and Evans High Technology Recruitment Index (HTRI) is another indicator of S/E labor market conditions. The HTRI measures the amount of advertising space in national newspapers devoted to recruiting scientists and engineers. Starting in 1975, the index measured 69. By 1979, the index had risen to 145, reflecting the surge in S/E recruitment that occurred toward the end of that decade. Following the recession in the early eighties, the HTRI dropped to 102 in 1983, before recovering strongly to 134 in 1984.

In the last 5 years, the HTRI has gradually declined, registering 103 in the second quarter of 1989—the lowest level of activity since 1983. (See figure 3-16 and appendix table 3-11.)

Summary

The employment indicators discussed above suggest that the labor market situation for scientists and engineers has been favorable since the mid-1980s. For example, it can be inferred from the relatively high participation rates and low unemployment rates that, in 1986, there was generally sufficient demand to accommodate the S/E labor force

Figure 3-15.
Degree field of 1984 and 1985 S/E graduates working as computer specialists in 1986



See appendix table 3-9. *Science & Engineering Indicators—1989*

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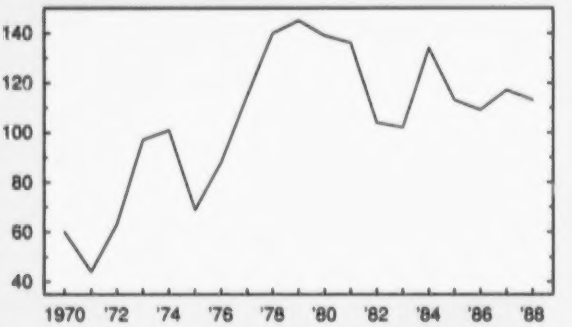
[20] NSF (1982), p. 1.
[21] NSF (forthcoming).
[22] NSF (1988c), p. 30.

Figure 3-16.
Deutsch, Shea, and Evans High Technology Recruitment Index: 1970-88

(Index 1961 = 100)



See appendix table 3-11. *Science & Engineering Indicators—1989*

(including recent S/E graduates). In addition, the moderate levels of shortages reported by employers in 1988 and the declining S/E HTRI would indicate that—with the exception of engineering Ph.D.s—the S/E labor force has, in general, been nearly sufficient to meet the economy's current needs. Finally, the data indicate that women and blacks are generally better utilized (relative to men and whites) in engineering than in the sciences.

On the other hand, however, the balance between supply and demand for S/E personnel has been accomplished through means other than new S/E graduates with fully appropriate training in their occupational field. Substantial occupational mobility[23] and increasing reliance on foreign-origin personnel (native-born U.S. citizens declined from 90 percent of the S/E labor force in 1972 to 83 percent in 1982)[24] have been largely responsible for the supply/demand equilibrium in the science and engineering labor market.

PROJECTED S/E DEMAND IN INDUSTRY

Over the 1988-2000 period, U.S. private industry is expected to create more than 600,000 additional jobs for scientists and engineers.[25] S/E employment is projected to increase by over 33 percent, nearly four times that of the overall industrial labor force. (See figure 3-17.) Despite the substantial growth, the projected gains in S/E requirements should not match past increases, due to the overall slowdown expected in the 1990s of growth in the labor force, total employment, and GNP.

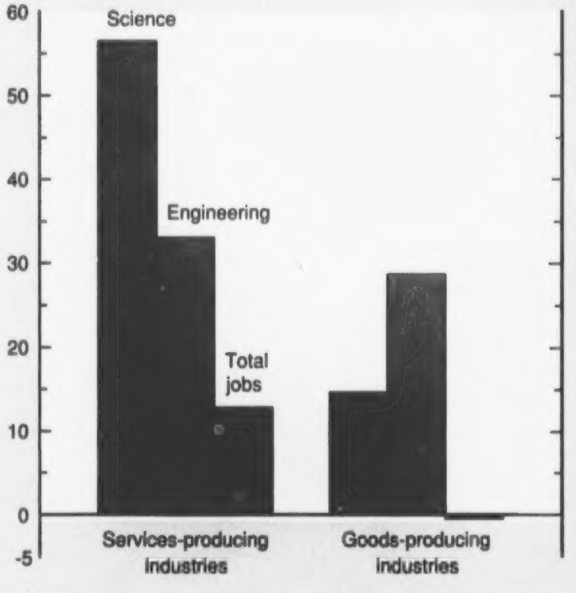
Services-Producing Industries

The 2.5 million S/E jobs in the year 2000 are expected to be somewhat more concentrated in services-producing industries than were the 1.9 million S/E jobs in 1988, because almost three-fifths of the increase in S/E jobs is projected to be in this sector. The faster creation of S/E jobs in the services-producing sector should continue the trend observed since 1980. At the projected rates of growth, the proportion of science jobs in the services-producing industries would increase from 62 percent in 1988 to almost 68 percent by 2000; the percentage of engineering jobs would go from 35 percent to 36 percent during this period. (See figure 3-18.)

Total job growth is expected to be very strong for almost all of the services-producing industries through the year 2000. By that time, services-producing employment should constitute about 70 percent of all private industry jobs. Almost 7 million new jobs are projected to be added to the sector between 1988 and 2000.

Figure 3-17.
Projected increase in science, engineering, and total jobs in private industry: 1988-2000

(Percent)



See appendix table 3-1. *Science & Engineering Indicators—1989*

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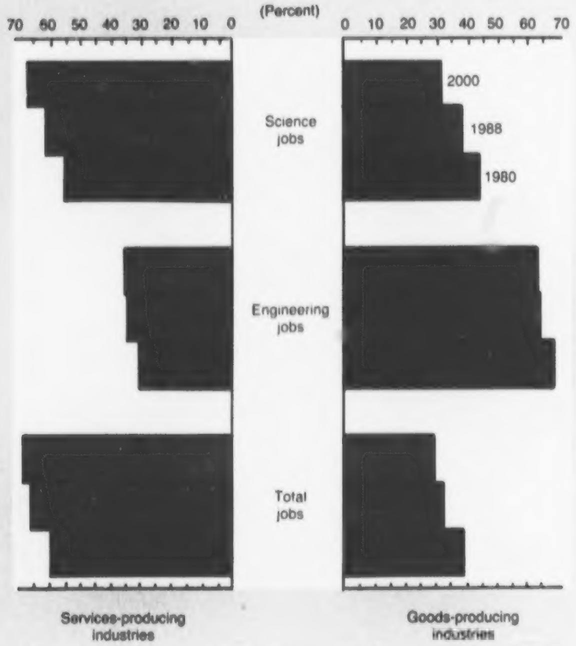
[23] Dauffenbach and Finn (1984).

[24] NSF (1986), p. 39.

[25] The projections of private industry's requirements for scientists and engineers used here were generated by NSF utilizing a modeling system developed by Data Resources (DRI), a private firm specializing in economic forecasting. NSF specified three projection scenarios—a "low," a "high," and a "mid"—using alternative sets of economic assumptions designed to encompass likely private sector performance during the simulation period of 1988-2000. (See appendix table 3-1a.) Based on these assumptions, the DRI model generated estimates of projected total employment by industry. The occupational structure applied to the total employment projections was developed by BLS.

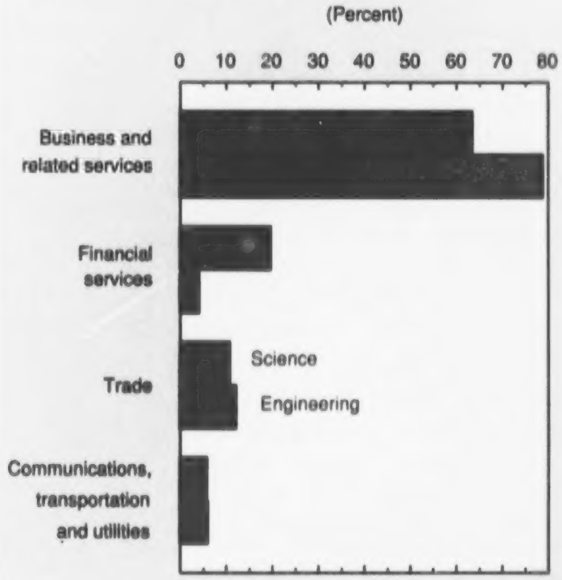
The scenarios are *not* predictions; consequently, departures from the assumptions on which the scenarios are based may alter future outcomes significantly. Three estimates of future requirements were prepared—a low, a high, and a mid trend; analysis here focuses on the mid trend.

Figure 3-18.
Proportion of science, engineering, and total jobs in private industry, by sector: 1980, 1988 and projected 2000



See appendix table 3-1. *Science & Engineering Indicators—1989*

Figure 3-19.
Distribution of new S/E jobs to be created in services-producing industries: 1988-2000



See appendix table 3-1. *Science & Engineering Indicators—1989*

Jobs for scientists and engineers are expected to grow even faster than total sector employment due to an increasing share of that employment. Overall, employment in services-producing industries is projected to be about 13 percent higher in 2000 than in 1988; S/E employment is expected to increase by almost 44 percent. The proportion of the services-producing workforce in S/E jobs is projected to increase during this time from 1.6 percent in 1988 to 2.0 percent by 2000, providing jobs for approximately 550,000 scientists and 600,000 engineers.

Business and Related Services. This division will be the sector's major provider of new S/E jobs through the year 2000. About two-thirds of the new science positions and three-fourths of the new engineering jobs expected to be created in the services-producing sector will be generated in this division. (See figure 3-19.) The number of S/E positions in business and related services industries is expected to rise by almost 65 percent to about 740,000—this represents 64 percent of the sector's S/E jobs in 2000.

Growth in this division will derive from the need for systems design and analysis and software development. This need is expected to continue to be very strong, reflecting the increasing demand for specialized systems by business and government, as well as the proliferation of packaged software for a wide variety of users. BLS projects that heavy investment in computer-assisted design and manufacturing techniques will lead to a continuing increase in the demand for computer specialists.[26] In addition, the development of new services should keep demand for independent research laboratories and management and other consulting firms very strong.

The engineering and architectural services industry—the largest employer of engineers in the private sector—is expected to turn around from current declines brought on by low demand in recent years for its services by a principal customer, the nonresidential construction industry. The latter is projected to recover from the recent oversupply of office and commercial space, and will resume modest growth. Consequently, S/E job opportunities in engineering and architectural services will increase.

Financial Services. S/E jobs in this division should continue to grow faster than in most other industries. As the growth in demand for financial services proceeds unabated, S/E jobs are expected to increase from 122,000 in 1988 to almost 168,000 in the year 2000, reflecting greatly increasing use of computerized services and technological advances.

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[26] For an analysis of long-range economic trends and their projected impact on employment, see Personick (1987).

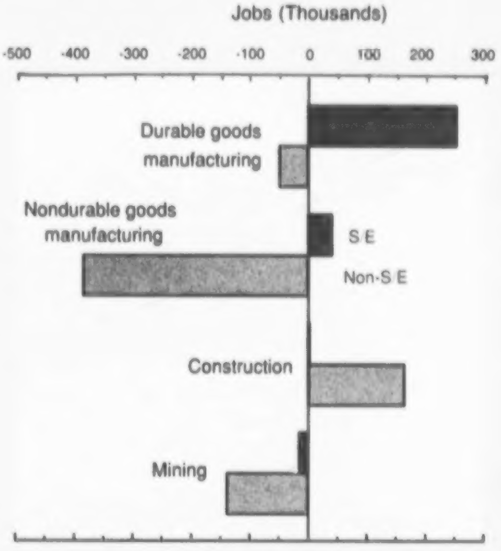
Goods-Producing Industries

The goods-producing industries are projected to provide almost 1.1 million jobs for engineers and 270,000 jobs for scientists by 2000. Like the trend observed between 1980 and 1988, there will be little if any growth in total employment in the goods-producing sector: declines in mining and nondurable goods manufacturing will offset small growth in construction and durable goods manufacturing. Output growth in most manufacturing industries is expected to continue at near current rates without a coincident growth—and even (for some industries) with declines in—total employment. The forces behind this output growth are:

- Investment, leading to higher productivity of the manufacturing workforce; and
- The growing quality of the services purchased from the services-producing sector.[27]

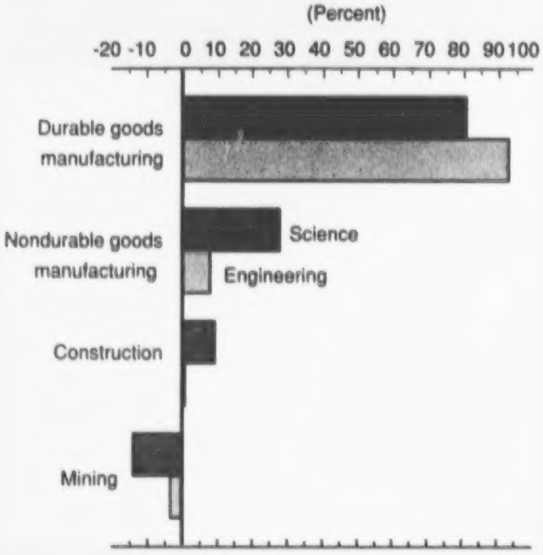
Most of the increase in U.S. manufacturing S/E personnel should be in durable goods. (See figure 3-20.) While employment in non-S/E occupations in this division is projected to decline slightly over the 12-year period, S/E jobs are expected to rise by 256,000, or 32 percent. (See figure 3-21.) Nondurable goods industries are projected to lose a substantial number of non-S/E jobs, even as growth in output continues at or higher than current rates. Due to occupational restructuring, however, S/E employment in these industries should increase by about 17 percent.

Figure 3-21.
Projected change in number of S/E and non-S/E jobs in goods-producing industries: 1988-2000



See appendix table 3-1. *Science & Engineering Indicators—1989*

Figure 3-20.
Distribution of new S/E jobs to be created in goods-producing industries: 1988-2000



See appendix table 3-1. *Science & Engineering Indicators—1989*

Occupations

During the 1988-2000 period, the occupational composition of industry jobs is expected to change, shifting away from production and assembly-line jobs toward professional, managerial, and technical occupations. Thus, while industry as a whole is expected to provide approximately 9 percent more jobs between 1988 and 2000, employment opportunities for S/E jobs are projected to increase by about 34 percent. The disproportionate rise in S/E jobs will result from general requirements for a higher proportion of workers with more education than in the past, and because the need to remain competitive will require an increasing number of S/E workers to update product designs, explore more cost-effective technology for producing goods, and develop new products.[28]

The S/E occupation benefitting most from these trends has been, and should continue to be, that of computer specialist. This occupation is expected to have the largest employment gain (197,000 jobs) and the fastest growth (62 percent) of any S/E occupation. (See figure 3-22.) About half of the employment gain for computer specialists is projected to occur in the business services division, primarily in computer and data processing services. The remaining increase should be spread throughout industry, as computers continue to be used more intensively by more industrial employers. New business and defense applications are expected to continue to be primary sources of requirements for computer specialists.

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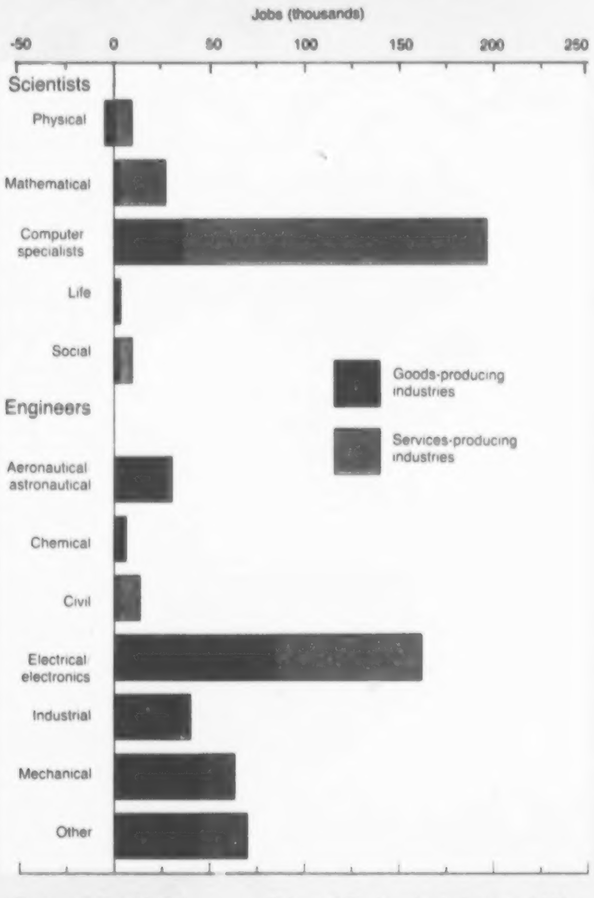
[27] Hirschhorn (1987), p. 9.

[28] For an excellent discussion of the economic factors affecting occupational pattern changes, see Silvestri and Lukasiewicz (1987). Also see Personick (1987).

The electrical/electronics engineering occupation is projected to have the next biggest absolute employment gain, up by 162,000 jobs or by nearly 40 percent. This increase is expected to be divided almost equally between the goods- and services-producing sectors, with increases of 84,000 and 78,000, respectively. These engineering jobs should be primarily in the manufacturing industries producing communications equipment, computers, and other electronics equipment, and in the engineering and architectural firms servicing these industries.

Figure 3-22.
Projected change in number of S/E jobs in private industry, by occupation and sector: 1988-2000



See appendix table 3-1. *Science & Engineering Indicators—1989*

S/E SUPPLY OUTLOOK

Stock and Flow of the S/E Labor Market

The flows of scientists and engineers into and out of the S/E workforce are highly complex due to the many forces affecting them. Additionally, there is a lack of concurrent and comparable data on all of the segments comprising new supply to and attrition from S/E employment. To approximate the magnitudes of S/E flows and their relative contributions to the overall stock of scientists and engineers, data from several different sources and time periods have been used and certain judgments exercised. No attempt is made here to infer current or future supply/demand relationships from these data, but rather to illustrate the relative magnitudes of these flows—insofar as possible—from the historic data available.

These flows are highly sensitive to such factors as:

- S/E supply/demand conditions, including economic growth;
- Defense and R&D spending;
- The population demographics, interest, and capabilities affecting the number of new entrants and attrition from the stock;
- Legislation and policy affecting the entry of foreign students and immigrants; and
- Policies and laws regulating retirement ages, etc.

The data in figure 3-23 are illustrative of the relative importance and magnitudes of the stock and the various flows. For this analysis, the most recent available estimates of the various stocks and rates of inflows and outflows are used to approximate the dynamics of change in the overall stock of natural scientists, engineers, and computer specialists (NS,E&CS) between 1985 and 1986.[29]

The stock of employed natural scientists, engineers, and computer specialists in 1986 reflected:

- Those who remained in NS,E&CS employment from the previous year—about 92 percent of the 1985 total;

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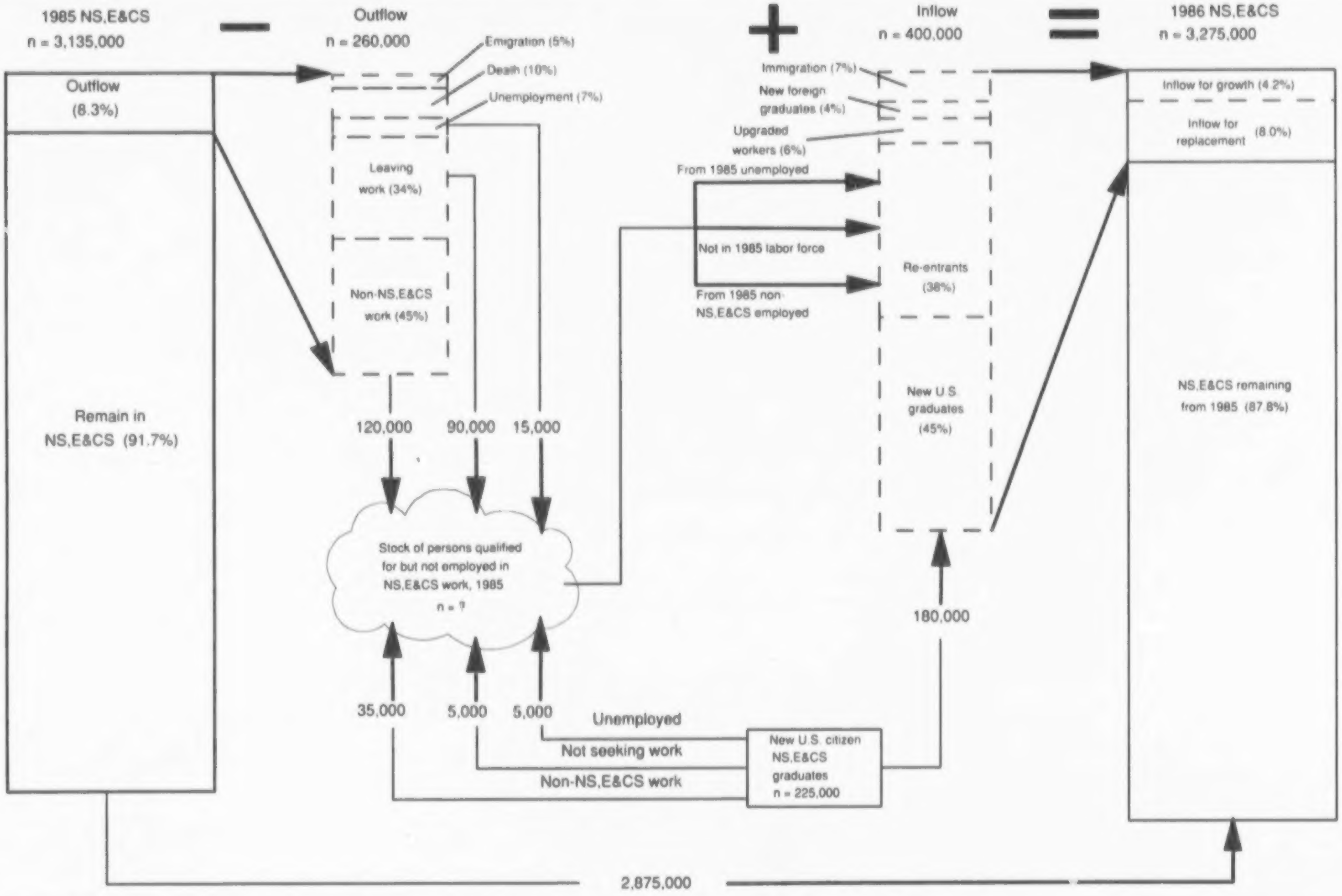
[29] Comparable estimates for social and behavioral scientists are shown on appendix table 3-12. Unpublished tabulations by BLS from the 1985 and 1986 Current Population Surveys and the 1986 Occupational Employment Statistics survey were used to develop estimates of the stock of persons employed in S/E occupations. For more information on these surveys, see U.S. BLS (1982). Elsewhere in this chapter, 1986 data are presented on the characteristics of persons who are classified as scientists or engineers based on their education and experience. These data are not strictly comparable with the information in this section, which describes S/E occupational patterns.

Figure 3-23.
Estimated changes in NS,E&CS stock and flow: 1985-86


1985 NS,E&CS
n = 3,135,000
Outflow
(8.3%)
Remain in
NS,E&CS (91.7%)
Outflow
n = 260,000
Emigration (5%)
Death (10%)
Unemployment (7%)
Leaving
work (34%)
Non-NS,E&CS
work (45%)
120,000
90,000
15,000
Stock of persons qualified
for but not employed in
NS,E&CS work, 1985
n = ?
35,000
5,000
5,000
Unemployed
Not seeking work
Non-NS,E&CS work
New U.S. citizen
NS,E&CS
graduates
n = 225,000
Inflow
n = 400,000
Immigration (7%)
New foreign
graduates (4%)
Upgraded
workers (6%)
From 1985 unemployed
Not in 1985 labor force
From 1985 non-
NS,E&CS employed
Re-entrants
(38%)
New U.S.
graduates
(45%)
180,000
1986 NS,E&CS
n = 3,275,000
Inflow for growth (4.2%)
Inflow for
replacement (8.0%)
NS,E&CS remaining
from 1985 (87.8%)
2,875,000

Notes: NS,E&CS = employed in natural science, engineering, and computer specialist jobs. Absolute numbers rounded to nearest 5,000.
See appendix table 3-12.

Science & Engineering Indicators—1989

- Outflows of workers who left NS,E&CS employment, i.e., those who left the labor force, switched occupations to non-NS,E&CS employment, became unemployed, died, or emigrated—about 8 percent of the 1985 total; and
- Inflows from persons who re-entered NS,E&CS work, recent graduates who took NS,E&CS jobs, technicians and other skilled workers who upgraded to or obtained NS,E&CS positions, and foreign scientists and engineers.

Between 1985 and 1986, it is estimated that about two-thirds of such inflows were required to replace workers who left NS,E&CS employment; the remaining one-third covered the growth in NS,E&CS jobs that stemmed from economic expansion, increased military expenditures, greater technological intensity, additional R&D, et al.

Outflows From NS,E&CS Employment. The total estimated outflow during 1985 from the employed NS,E&CS workforce was about 8 percent of those employed as natural scientists, engineers, and computer specialists at the beginning of the year. The remaining 92 percent of the NS,E&CS workers stayed in NS,E&CS work and comprised the bulk of the NS,E&CS workforce the following year.

Of the 8 percent of the workers who left NS,E&CS employment, the largest outflow—over two-fifths—was of persons changing to non-NS,E&CS occupations, followed by persons exiting the labor force (e.g., retirees, those returning to school, those choosing to stay at home to rear children, etc.)—about one-third. The remainder of the outflow included aliens previously admitted to the U.S. and naturalized citizens who emigrated, those who became unemployed, and those who died.[30] Each of these groups (except the last) represents a possible source of re-entrants to the NS,E&CS workforce.

Inflows to NS,E&CS Employment. Entrants are needed to fill the new NS,E&CS jobs created by economic growth and the increasing demand for NS,E&CS personnel. In addition, replacements must be found for people who leave the workforce. About 260,000 of those employed as natural scientists, engineers, and computer specialists left the NS,E&CS workforce between 1985 and 1986. Analysis of the 1986 stock shows that, besides the replacements needed for this outflow, an additional 140,000 people were hired to fill the approximately 5-percent increase in total NS,E&CS jobs created between 1985 and 1986. The total estimated NS,E&CS inflows of 400,000 are equivalent to about 12 percent of the 1986 NS,E&CS stock of 3.3 million.

New U.S. citizen NS,E&CS graduates were the largest component of the total inflow to the 1986 stock, approximately 45 percent.[31] The second largest portion of the inflow, 38 percent, consisted of re-entrants to the NS,E&CS workforce of scientists and engineers who were doing non-NS,E&CS work or who were temporarily out of the labor force.[32] The recent foreign graduates of U.S. colleges and universities and direct immigration of experienced foreign NS,E&CS together accounted for about 10 percent of the inflow.[33] About 5 percent of the inflow were estimated to be persons who were upgraded to engineering jobs.[34]

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[30] *Attrition* out of the labor force (except for death and emigration) was calculated by applying occupation-specific separation rates for the 1983-84 period. See U.S. BLS (1986), table C-1. *Annual transfer rates* to non-NS,E&CS occupations were estimated from longitudinal survey data of scientists and engineers in the 1980 population by their occupational status in 1982 and 1984 from tabulations of unpublished NSF data prepared by Dr. Robert Dauffenbach, Oklahoma State University. The transfer rates do not include persons who transferred to manager/administrator jobs if these were related to the management or administration of NS,E&CS activities. The transfer rates also do not apply to transfers among NS,E&CS fields, but only out of the total NS,E&CS workforce. *Annual death rates* by sex and age are from estimates for the population by the Bureau of the Census for the 1985-90 period applied to NSF distributions of scientists and engineers by age and sex. The "Low Mortality Assumption" table was used to account for differences in racial mix and type of employment between the general population and NS,E&CS workers. See U.S. Bureau of the Census (1984), table B-1A. *Unemployment* does not include the stock of unemployed in 1985, but only the net change in unemployment from 1985 to 1986. Unemployment rates are from unpublished BLS occupation-specific data. See U.S. BLS (1986). *Emigration rates* were estimated separately for naturalized U.S. citizens and aliens. The rates are derived from estimates of average emigration for the 1981-85 period. See Finn and Clark (1988). The estimates for emigration assume that there is no net emigration of natural-born citizens. The data on *alien S/E admissions* are from the U.S. Immigration and Naturalization Service.

[31] The estimates for new bachelor's and master's degree graduate entrants are from NSF (1987); the estimates for new Ph.D. recipients are from NSF (1988d). The data for new bachelor's and master's degree recipients are for the labor force status in 1986 of 1985 graduates who were not full-time graduate students in 1986. The data exclude foreign students who had a foreign address at the time of the survey.

The labor force entrance rates for the 1985 graduates were adjusted upward, based on the status of 1984 graduates in 1986. The longer postgraduation lag time was used to provide a more realistic estimate of the contribution of recent graduates to the NS,E&CS workforce, since participation rates increase substantially between the first and second year after leaving school. The data were also adjusted for an estimate of double counting of master's degree recipients and Ph.D.s who may already have been employed in NS,E&CS jobs while in graduate school. Downward adjustments for Ph.D.s were made for those reporting their major source of support in graduate school as teaching or research assistantships, employer funds, or own earnings. The rates for employer funds and own earnings for Ph.D.s were applied to the master's new entrants, as such data are not collected for them.

All bachelor's new entrants were assumed to be first-time entrants. The aforementioned surveys of new entrants do not include those receiving the bachelor's of technology degree. An estimate for bachelor's of technology degree recipients who became NS,E&CS workers was calculated by assuming the same labor force participation rates as for engineering bachelor's degree recipients and applying that rate to the 19,600 technology degrees awarded in 1985. The resulting 16,600 new entrants are included in the inflow to the NS,E&CS workforce.

[32] This proportion is the remainder of the inflow requirements for growth and replacement after accounting for the inflows of new graduates, immigrants, and worker upgrading.

[33] Estimates for foreigners receiving U.S. bachelor's and master's degrees are from flow rate estimates for 1981-82 from Finn (1985). Data for foreigners with U.S. Ph.D.s are for 1985 from NSF (1988d).

[34] In 1982, there were about 171,000 persons employed as engineers without a bachelor's degree, or roughly 16.3 percent of the employed engineering workers. See NSF (1984). These persons are loosely designated as "upgraded workers." It is assumed that upgrading to engineer status for meritorious non-degreed persons from among the nearly 1 million engineering technicians and other persons with S/E training would continue at about the same rate so as to maintain their share of total engineering jobs.

The 180,000-person inflow of new U.S. citizen NS,E&CS graduates between 1985 and 1986 was greater than the 140,000-person increase in total NS,E&CS jobs created during this period. The difference (40,000) is the amount that the total outflow from 1985 exceeded the total inflow to the 1986 stock, excluding new graduates.

The Stock of Possible NS,E&CS Re-Entrants. As noted above, almost 40 percent of the inflow to the 1986 NS,E&CS stock were re-entrants to the employed NS,E&CS workforce. Included in this group are:

- Natural science, engineering, and computer science graduates[35] who had delayed entering the labor force, even though they are not, strictly speaking, re-entrants;
- NS,E&CS personnel who were employed in non-NS,E&CS jobs in 1985; and
- Other NS,E&CS personnel who had not worked in that year, including retirees from NS,E&CS employment and those who temporarily left the labor force for child rearing or other reasons.

The size of this group cannot be estimated reliably. There are substantial numbers of persons of working age with formal training in science and engineering who are not employed in NS,E&CS occupations. For example, in the 25 years between 1961 and 1986, 3.9 million bachelor's degrees in the natural sciences, engineering, and computer science were awarded in the United States, or roughly 800,000 more than the number of persons employed in NS,E&CS occupations. However, the ability of this group to meet exigencies of possible future shortfalls in the supply of new entrants is not known. The propensities of entry to NS,E&CS jobs would vary substantially depending upon the level of NS,E&CS training and experience held by these persons, their age, their attachment to their current employment or other labor force status, how long they have been away from NS,E&CS work, and on labor market conditions affecting employers' willingness to hire or retrain such qualified persons or to pay sufficient wages to attract qualified potential re-entrants from high-paying positions outside the NS,E&CS workforce.

Further—to the extent that the stock of potential NS,E&CS re-entrants does not match workforce requirements by occupation, skills, or experience—the ability to supply needed workers will be limited. This group merits further study to address its contribution to the NS,E&CS workforce.

Summary. The following summarizes the major points of this analysis of the stock and flow of natural scientists, engineers, and computer specialists between 1985 and 1986.

- Over the 1-year period of time, the stock was over 10 times as large as the flow. A little more than 8 percent of the 1985 NS,E&CS workforce left and just over 12 percent of the 1986 NS,E&CS were new or re-entrants.
- The most important factors in the estimated 1985 outflow were those moving to non-NS,E&CS work (over two-fifths) and those leaving work (over one-third). Each of the other factors—death, unemployment, emigration—accounted for one-tenth or less of the outflow. Since the total outflow was less than 9 percent of the total stock, this means that each of these three other outflow factors accounted for between about 0.3 percent and 0.8 percent of the estimated 1985 stock.
- About two-thirds of the NS,E&CS inflows were used to replace outflows, while the other one-third was used for the growth in NS,E&CS employment. The most important factors in the estimated inflows to the 1986 NS,E&CS were new U.S. citizen graduates (about 45 percent) and re-entrants (about 40 percent). Each of the other factors—worker upgrades, immigration, and new foreign graduates—accounted for 7 percent or less of the inflow. As the total inflow was only about 12 percent of the total stock, this means that each of these latter three inflow sources accounted for between about 0.4 percent and 0.9 percent of the estimated 1986 stock.

The acknowledged lack of statistical precision in procedures used to estimate some of the minor factors in this section have relatively little effect on the results, as shown by some sensitivity testing. If, for example, the estimate for worker upgrades (admittedly a difficult number to estimate given current data) is off by as much as ±50 percent, the relative impact of this group on the 1986 stock would be between 0.4 percent and 1.1 percent—i.e., (25,000 ± 12,500)/3,275,000. Similarly, the other, smaller factors for which estimates incorporating judgment had to be used would have minor impact even if a range of ±50 percent were used to sensitivity-test the effect of the estimating procedures.

Given the high degree of stability of the stock of NS,E&CS employed and the demonstrated availability of multiple sources of supply, it is clear that substantial adjustments to changing supply and demand conditions in the NS,E&CS labor market are possible. The major remaining questions about such adjustments are their costs (in terms of time and resources), whether they would be sufficient to meet a sustained increase in demand, and how the quality of NS,E&CS personnel would be affected.

Outlook

As long as the Nation maintains a vigorous economy, spot shortages and surpluses in some S/E fields seem to be unavoidable, as typified by recent shortages in some engineering subfields and computer specialties. While market forces generally have been able to remedy such imbalances in the past, future corrective actions may require increased or new Federal policy measures. To meet the anticipated increase in demand for S/E personnel in the 1990s, several adjustments may have to occur because:

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[35] For purposes of this analysis, recent graduates who are full-time graduate students are not included in the potential pool since estimates of their post-school employment status are made after they leave school.

- The size of the traditional 18- to 24-year-old college-age cohorts will decline through the early 1990s, and
- Retirements may increase due to larger proportions of experienced S/E workers reaching 55 or older.

Shortages may not necessarily develop. Some of the gap may be filled by increased enrollment of the 18- to 24-year cohort as well as older students and foreigners, many of whom remain to work in the United States. In addition, small shifts in the percentages of students choosing to train in S/E fields, and in the proportions of graduates who choose to enter S/E employment fields, could provide an adequate supply of new entrants to the S/E workforce.[36]

There are other adjustments that can also occur. Labor force mobility is particularly important in instances of tight markets when newly trained S/E entrants and S/E personnel in the experienced pool may be induced to leave their current fields of specialization and transfer into higher demand fields. This is what occurred in satisfying the very high growth in demand for computer specialists. There may also be fewer S/E-trained people attracted to non-S/E jobs. Additionally, there may be delays in retirements of S/E workers in response to needs for their services; this has been the case in past engineering shortages. Finally, employers may provide training and upgrading of technician personnel.

What is uncertain is the magnitude of these possibly required adjustments. Past experience indicates that these supply movements, together with adjustments made by employers, have been generally sufficient to meet the growing demand for S/E personnel;[37] projecting ahead, however, is much more complex. For example, although it is known that women, ethnic minority, and older students are a rising proportion of all undergraduates, it is uncertain how many of them will enter S/E employment fields. Also, while it is believed that adjustments in enrollment patterns will be made in response to a growing demand for S/E graduates, it is not clear that any adjustments will be sufficient to provide an adequate supply in the future. Further, many of the adjustments noted above could entail substantial costs and possibly affect the quality of the S/E workforce.

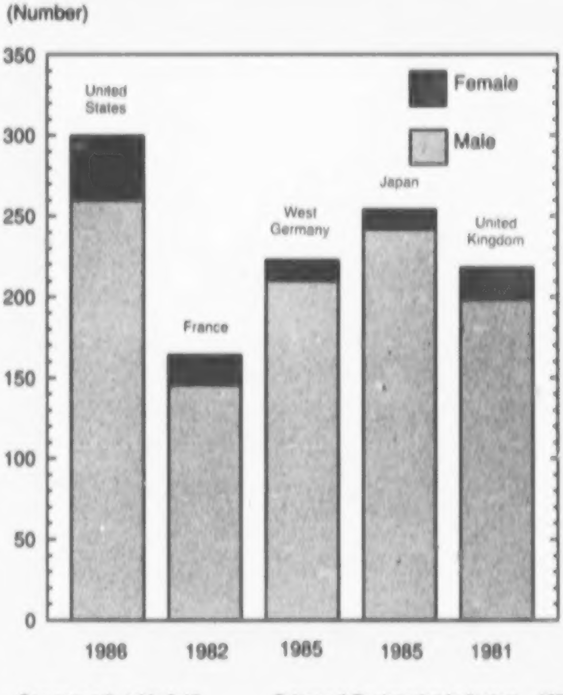
INTERNATIONAL EMPLOYMENT OF SCIENTISTS AND ENGINEERS

The employment of scientists and engineers is a significant indicator of the level of effort and relative national priority for science and technology among major industrial countries. While problems of comparability exist because of differences among countries in their methods of data collection and estimation, international employment data provide meaningful insight into the relative strengths of the S/E workforces in the United States and other countries.

In the early to mid-1980s, the number of nonacademic scientists and engineers employed in the United States exceeded the combined total of those in France, West Germany, Japan, and the United Kingdom. This result was not unexpected, because the total U.S. population is about the same as that of the other countries combined. Examining the number of scientists and engineers as a proportion of each country's total labor force showed that the United States employed the highest percentage of scientists and engineers, followed closely by (in descending order) Japan, West Germany, the United Kingdom, and France. (See figure 3-24.) In all countries examined, service industries predominated among employers of scientists, while manufacturing industries employed the largest proportions of engineers.

In the United States and Japan, a quarter of the scientists and engineers employed in manufacturing industries in the early to mid-1980s were electrical/electronics engineers. Manufacturing industries in France employed relatively more civil engineers than in the other countries; West Germany employed a relatively greater proportion of natural scientists. A much higher proportion of Japan's

Figure 3-24.
Nonacademic scientists and engineers per 10,000 labor force for selected countries, by gender



See appendix table 3-13. *Science & Engineering Indicators—1989*

scientists and engineers were employed in service and construction industries, while scientists and engineers in the United States were more evenly divided between manufacturing/mining industries and service industries. In France, a very high percentage of scientists and engineers worked in the government sector. (See figures 3-25 and 3-26.)

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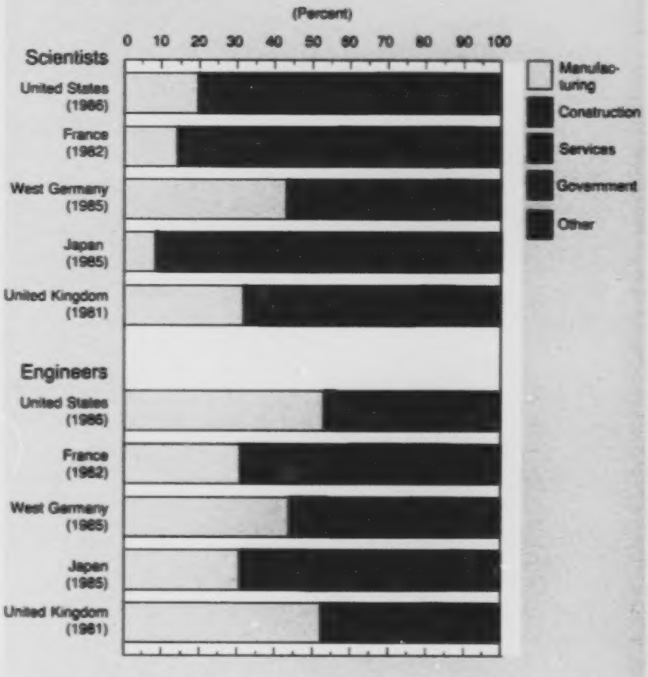
[36] Hansen (1986).

[37] For instance, a recent report from the National Research Council concluded that, since 1972, a substantial portion of job openings for engineers has been filled from pools other than the traditional supply source of new U.S. citizen engineering recipients, and that the supply of engineering talent has, therefore, been capable of adjusting to wide swings in employment. See NRC (1988), pp. 37-38.

In absolute terms, the United States has the largest number of scientists and engineers working in R&D of any country. (See figure 3-27.) As a proportion of the labor force, however, other countries now have concentrations of R&D scientists and engineers approximating that of the United States. In 1986, Japan's ratio per 1,000—6.74—was nearly identical to that of the United States—6.62.

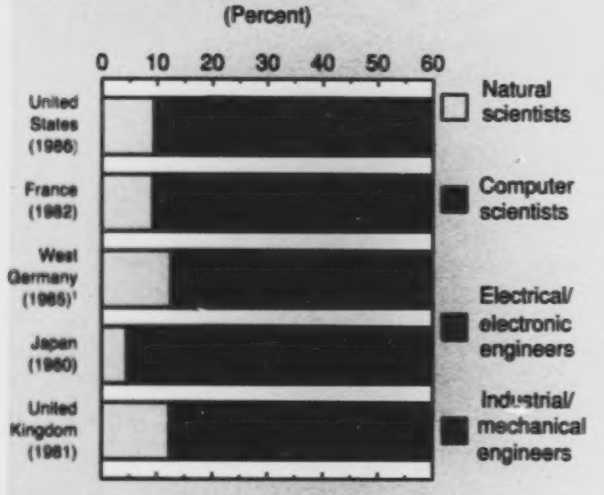
The United States led the United Kingdom in the number of scientists per 1,000 total labor force (12 versus 8 per 1,000) and was second to Japan in the number of engineers per 1,000 labor force (18 versus 19 per 1,000) in the early 1980s. However, the U.S. ranked first among the countries compared in the ratio both of scientists and of engineers with university degrees.[38] In West Germany, most engineers have qualifications from technical colleges.[39] Of the reported scientists and engineers in the United Kingdom, less than half have a university degree. Nonetheless, some of these countries may have stronger training in science and mathematics at the precollege level.

Figure 3-26.
Nonacademic scientists and engineers in selected countries, by sector of employment



See appendix table 3-15. *Science & Engineering Indicators—1989*

Figure 3-25.
Scientists and engineers in manufacturing for selected countries, by occupation group



[1] Computer scientists are included under natural scientists as well as electrical/electronic engineers.
See appendix table 3-14. *Science & Engineering Indicators—1989*

The United Kingdom, France, and West Germany all had a greater concentration of first university degrees in the natural sciences in 1986 than did the United States. (See figure O-7 in Overview.) In absolute numbers, however, the U.S. degree recipients were more numerous. In 1982, Japan graduated more engineers at the bachelor's level than did the U.S., but by 1983, the number of U.S. engineering graduates was 5 percent greater due to an 8-percent increase in the number of U.S. graduates and a 5-percent drop in Japanese engineering degrees. The U.S. awards more than twice the number of engineering doctoral degrees and more than 10 times the number of natural science doctorates than does Japan.

The age of a country's S/E labor force can be an indicator of the recency of training and its future capabilities. Japan had the youngest scientists and engineers of the five countries, including the United States: in 1985, almost half of the Japanese nonacademic scientists and engineers were under 35 years old, and only 7 percent were 55 or older. This supports recent observations about the high output of the Japanese educational system. About half the scientists and engineers in France, West Germany, and the United States were between 35 and 54 years old. (See figure

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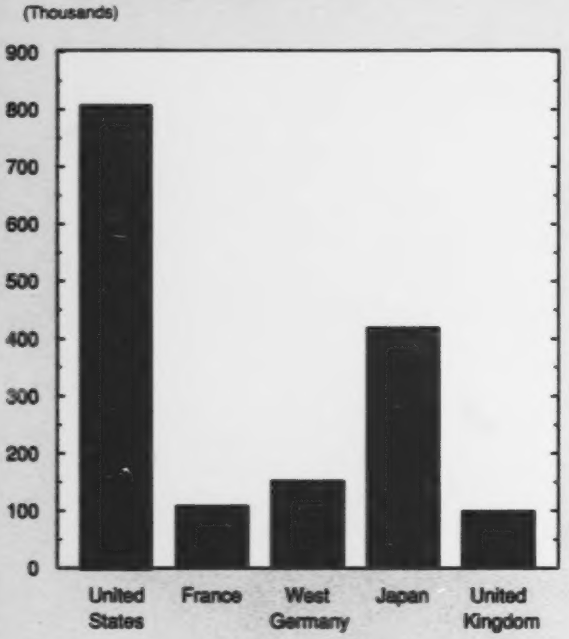
[38] Way and Jamison (1986), p. 2.

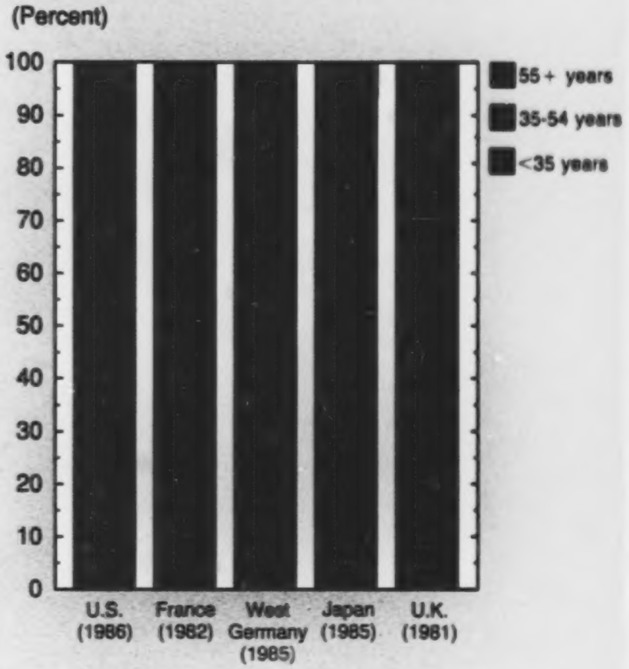
[39] For comparability, only engineers with university degrees are used for comparisons. West German engineers trained in professional colleges generally have received more specialized and technically intensive training; university degree recipients have received broader and more academic engineering training.

Figure 3-27.
Scientists and engineers engaged in R&D for selected countries: 1987



Note: United States and United Kingdom data are for 1986, all others are 1987.
See appendix table 3-16. *Science & Engineering Indicators—1989*

Figure 3-28.
Nonacademic scientists and engineers in selected countries, by age group



See appendix table 3-17. *Science & Engineering Indicators—1989*

3-28.) On average, women scientists and engineers were younger than their male counterparts in all countries.

When all five countries were compared, the vast majority of engineers were men, with the small proportion of females slowly increasing. Science occupations also were predominantly male, but with a larger percentage of women represented. The United States, France, and the United Kingdom had the best records of using female scientists and engineers (10 percent). Only 6 percent of scientists and engineers in West Germany were women; nearly half of these were social scientists. In Japan, women comprised only 5 percent of the scientists and engineers. Nearly half of these women were computer scientists.

REFERENCES

Council of Economic Advisers. 1989. *Economic Report of the President*. Washington, DC: Government Printing Office.

Dauffenbach, R.C., and M.G. Finn. 1984. "Employer Provided Training and the Issue of Quality in the Engineering Work Force." Oak Ridge, TN: Oak Ridge Associated Universities.

Finn, M.G. 1985. *Foreign National Scientists and Engineers in the U.S. Labor Force, 1972-82*. Oak Ridge, TN: Oak Ridge Associated Universities.

Finn, M.G., and S.B. Clark. 1988. "Estimating Emigration of Foreign-born Scientists and Engineers in the United States." Working paper. Oak Ridge, TN: Oak Ridge Associated Universities.

Hansen, W.L. 1986. "The Impact of Demographic Trends on the Scientific and Engineering Workforce." Testimony presented before the Science Policy Task Force, Committee on Science and Technology, U.S. House of Representatives.

Hirschhorn, L. 1987. *Skill Formation in the U.S. Service Economy*. Philadelphia: University of Pennsylvania, Wharton Center for Applied Research.

Market Facts, Inc. 1987. *1986 NSF Science and Engineering Labor Market Study*. Washington, DC: Market Facts, Inc.

National Research Council (NRC), Office of Scientific and Engineering Personnel, Committee to Study Engineering Labor-Market Adjustments. 1988. *The Effects on Quality of Adjustments in Engineering Labor Markets*. Washington DC: National Academy Press.

National Science Foundation (NSF). Forthcoming. *Young* *and Senior Science and Engineering Faculty and Nonfaculty Research Doctorates: 1986*. Washington, DC: NSF.

____. 1988a. *Women and Minorities in Science and Engineering*. NSF 88-301. Washington, DC: NSF.

____. 1988b. "Services Led in Private Industry Growth in Science/Engineering Jobs but Manufacturing Rebounds and Tops 1 Million in 1987." *Science Resources Studies Highlights*. NSF 88-304. Washington, DC: NSF.

____. 1988c. *National Patterns of Science and Technology Resources: 1987*. NSF 88-305. Washington, DC: NSF.

____. 1988d. *Science and Engineering Doctorates: 1960-86*. Science Resources Studies detailed tables. NSF 88-309. Washington, DC: NSF.

____. 1987. *Characteristics of Recent Science and Engineering Graduates: 1986*. Science Resources Studies detailed tables. NSF 87-321. Washington, DC: NSF.

____. 1986. *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*. NSF 86-305 (revised). Washington, DC: NSF.

____. 1984. *The 1982 Postcensal Survey of Scientists and Engineers*. NSF 84-330. Washington, DC: NSF.

____. 1982. "Labor Markets for New Science and Engineering Graduates in Private Industry." *Science Resources Studies Highlights*. NSF 82-310. Washington, DC: NSF.

Personick, V.A. 1987. "Industry Output and Employment Through the End of the Century." *Monthly Labor Review* 110, no. 9 (September): 30-45.

Silvestri, G.T., and J.M. Lukasiewicz. 1987. "A Look at Occupational Employment Trends to the Year 2000." *Monthly Labor Review* 110, no. 9 (September): 46-63.

Tschetter, J. 1987. "Producer Services Industries: Why Are They Growing So Rapidly?" *Monthly Labor Review* 110, no. 12 (December): 31-39.

U.S. Bureau of the Census. 1984. *Projections of the Population of the United States by Age, Sex, and Race: 1983 to 2080*. Series P-25, no. 952.

____. 1983. *General Social and Economic Characteristics, United States Summary*. 1980 Census of Population. Washington, DC: Government Printing Office.

U.S. Bureau of Labor Statistics (BLS), Department of Labor. 1987a. *Employment and Earnings* 34, no. 1 (January).

____. 1987b. *Employment and Earnings* 34, no. 2 (February).

____. 1987c. Supplement to the Current Population Survey. Unpublished data.

____. 1986. *Occupational Projections and Training Data, 1986 Edition*. Bulletin 2251. Washington, DC: Government Printing Office.

____. 1982. *BLS Handbook of Methods*. Bulletin 2134-1. Washington, DC: Government Printing Office.

Way, P.O., and E. Jamison. 1986. *Scientists and Engineers in Industrialized Countries*. Washington, DC: U.S. Bureau of the Census, Center for International Research.

Chapter 4
Financial Resources for Research and Development

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Financial Resources for Research and Development

HIGHLIGHTS

The Nation's investments in research and development (R&D) have continued to grow.

- *Total R&D investments are estimated to have increased by 44 percent since 1980 (in constant dollars), compared with an increase of 17 percent in the previous decade.* The estimated 1989 national investment reached $132 billion, or 2.6 percent of the gross national product (GNP). (See p. 87.)
- *In recent years, the rate of increase in these R&D investments has slowed.* From 1981 to 1985, total national expenditures for R&D averaged 6-percent growth per year, in constant 1982 dollars, in contrast to an estimated 2-percent annual growth between 1985 and 1989. Only R&D performed at academic institutions shows a high growth rate since 1985. (See p. 87.)

Except in the academic sector, patterns in R&D funding and performance have changed little in the 1980s.

- *During the 1960s and 1970s, Federal R&D funding decreased relative to industry funding.* But since 1980, Federal and industry shares have remained steady and about equal, at about 47 percent for the Federal share compared with an industrial share of about 48 percent. (See pp. 87-88.)
- *From 1980 to (estimated) 1989, Federal nondefense obligations declined 3 percent.* While Federal obligations for nondefense basic research increased 51 percent over the decade, cutbacks in development (-34 percent) and applied work (-10 percent), largely related to energy technologies, account for the net decline in nondefense Federal R&D obligations. (See p. 94.)
- *In the performance of R&D activities, relative sectoral shares have remained stable.* Private firms perform about 72 percent of total national R&D, universities about 11 percent, and the Federal Government about 11 percent. (See p. 88.)
- *In constant dollars, academic institutions have doubled investments of their own funds in R&D since 1980.* Academic institutions received Federal support for 59 percent of their R&D activities in 1989, down from 68 percent in 1980. As a percentage of the total R&D performed by this sector, the institutions' own funds grew from 22 percent to 27 percent over the same period, and industrial funds from 4 percent to 7 percent. (See pp. 88-89.)
- *In constant dollars, performance of R&D by industrial firms reflects aggregate national R&D patterns.* From 1980 to 1985, firms' R&D performance grew at about 5 percent annually; since 1985, this growth has slowed to less than 2 percent annually. (See p. 87.)

R&D investment priorities differ considerably among the industrialized countries.

- *The U.S. spends more on R&D than the United Kingdom, Japan, France, and West Germany combined.* (See pp. 3, 96.)
- *Japan and West Germany both invested a larger percentage of their 1987 GNPs in R&D (2.9 percent and 2.8 percent, respectively) than did the U.S. (2.6 percent).* Japan has now exceeded the U.S. on this indicator for 3 years (1985-87). (See p. 96.)
- *Japan, West Germany, France, and the United Kingdom combined invested $11 billion more than the U.S. in nondefense R&D.* Relative to GNP, Japan invested a percentage point more in nondefense R&D than the U.S. in 1987, and Japan's growth on this indicator has been rapid. Between 1979 and 1987, the U.S. increased its nondefense R&D/GNP ratio from 1.6 to 1.8, compared to increases for Japan of 2.0 to 2.6, for West Germany of 2.1 to 2.6, and France of 1.4 to 1.8. (See pp. 96-97.)
- *West Germany invested 15 percent of its total governmental R&D in industrial development, compared to less than 1 percent in the United States.* Japan invests heavily in energy-related R&D compared to the U.S.—23 percent versus 4 percent. (See p. 97.)
- *Among broad fields of academic R&D, the U.S. invests by far the largest proportion in the life sciences (49 percent), followed by 16 percent in the physical sciences and 13 percent in engineering.* In these same fields, Japan invests 34 percent, 15 percent, and 22 percent, respectively, of its total academic R&D. (See pp. 98-99.)

In response to shifting economic conditions and other factors, states have increased their support of science and technology (S&T) activities.

- *Funding of R&D from the states' own funds has more than doubled since 1977, reaching about $769 million in 1988.* The states are involved in a variety of activities in support of S&T, from research grant programs to provision of venture capital for company start-ups. However, total state funding of R&D from the states' own sources accounted for less than 1 percent of national R&D expenditures. (See pp. 101-102.)

This chapter discusses financial indicators of the Nation's research and development (R&D). The first section describes broad patterns in the funding and performance of R&D both in the current period and over the longer term. The patterns of interest are flows of financial resources among science and engineering (S/E) funding and performing institutions in the various sectors.[1]

The second section narrows the focus from total national R&D funding and performance to a consideration of the *character* of these activities—i.e., basic research, applied research, and development. Transfers of funds among R&D-funding and -performing sectors (government, academia, industry, and nonprofit institutions) show differing patterns for each sector across the various R&D activities and broad fields of science and engineering. Section three provides comparisons on similar R&D topics among the major industrialized countries.

A new, final section in this chapter presents indicators of support for science and technology (S&T) on the state level. A recent survey of state S&T funding agencies generated data on state agency expenditures for R&D, and these data are compared with those from the last such survey in 1977. The section also contains indicators of institutional development in the support of state-level S&T programs, and a discussion of the different types of programs these agencies use to foster S&T-based economic development.

NATIONAL R&D FUNDING PATTERNS

In 1989, the United States spent approximately 2.6 percent of its gross national product (GNP) on R&D activities, according to current estimates. This investment in the discovery of new knowledge—and in the application of knowledge to the development of new products, processes, and services—totaled an estimated $132 billion.[2]

This section discusses broad patterns in the Nation's R&D investment—specifically, patterns among R&D funders and performers, among the standard classifications of R&D work (basic, applied, and development), and across various governmental socioeconomic objectives, including defense- versus nondefense-oriented R&D.

Long-Term Trends

In constant 1982 dollars, the Nation's R&D expenditures have more than doubled over the past three decades, rising from about $44 billion in 1960 to an estimated $105 billion in 1989. (See appendix table 4-2.) Considerable structural changes in the patterns of R&D support and performance have accompanied this real expansion of R&D investment.

The most notable of these changes concerns the relative roles of the Federal Government and private industry in *funding*, or supporting, R&D. The Federal share of total national R&D expenditures has fallen steadily, dropping from 65 percent in 1960 to an estimated 47 percent in 1989. (See appendix table 4-2.) Over the same period, U.S. firms have increased their relative share of support for total U.S. R&D activities from 33 percent to 48 percent. This includes both in-house R&D and funding of R&D in other sectors. Also, university and college support for R&D grew over the three decades, rising from 1 percent to 3 percent of the national total. This growth in relative share has been even more pronounced in basic research.

R&D *performance* patterns have also changed, but in different ways. In contrast to their overall increased support for R&D, private firms are estimated to have performed a smaller share of R&D in 1989 than in 1960: 72 percent versus 78 percent, respectively. Research universities and colleges increased their share of R&D performance from 5 percent to 11 percent of the national total over the same period. This growth in R&D performed on the Nation's campuses has resulted from steadily rising sponsorship of R&D work by both the Federal Government and private industry, and from increased investments by the institutions themselves.[3]

Recent Trends

National investment in R&D generally rose in the 1980s—4 percent annually on the average. This growth has slowed during recent years, however. (See figure O-19 in Overview.) Compared to an average annual constant-dollar increase of over 6 percent in total national expenditures for R&D between 1981 and 1985, expenditures between 1985 and 1989 are estimated to grow only 2 percent per year. Industry's funding of its own R&D has slowed considerably, from average annual growth rates of 5 percent in the first half of the decade to an estimated less than 2 percent in the second half. (See appendix table 4-2.) Growth in Federal *in-house* R&D virtually halted over the past 4 years, down from increases of almost 7 percent per year between 1981 and 1985.

Only R&D performed by academic institutions continued to grow strongly throughout the decade, actually increasing its growth rates since 1985 to a 6-percent annual average.

1989 Patterns

Funds for R&D in the United States came mainly from two sources in 1989—private firms and the Federal Government. (See figure 4-1.) U.S. businesses used their own funds to finance 48 percent of the Nation's total investment in R&D; the Federal Government provided 47 percent. (See

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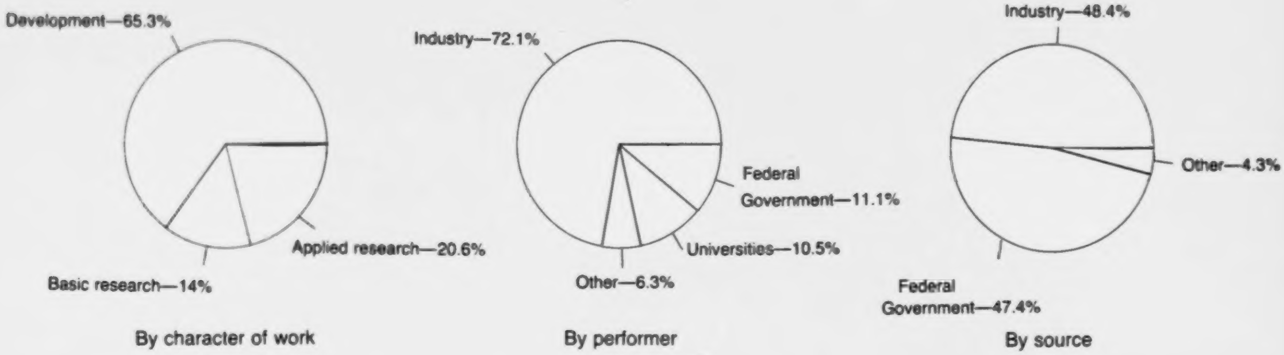
[1] Most of the data in this chapter are financial data, and changes in expenditures are taken as indicators of real changes in the amounts of S/E being funded and performed in the Nation. Since no single unit of new knowledge exists, funding and expenditure data *measure* monetary transfers among R&D-funding and -performing institutions, but only *indicate* changes in the "amount" of R&D being supported and performed. By necessity, then, this chapter discusses *science* as a process or activity; it does not discuss the results of this activity. See chapter 5 for other indicators of scientific processes and chapters 6 and 7 for S/E output indicators.

[2] Throughout this chapter, current funding or expenditure data are presented in current dollars. Trend data are usually deflated to 1982 constant dollars using the GNP implicit price deflator, and are identified as such. See appendix table 4-1.

[3] See chapter 5 for other indicators of these trends.

Figure 4-1.
National R&D expenditures: 1989



See appendix tables 4-2, 4-3, 4-4, and 4-5.

Science & Engineering Indicators—1989

text table 4-1.) The remainder of 1989 R&D funding came from universities and colleges and nonprofit institutions.

The role of private industry is larger in *performing* R&D activities than in *funding* them. In 1989, the estimated $95 billion in R&D performed by firms accounted for 72 percent of total national R&D performance. One-third of this was financed by the Federal Government. (See appendix table 4-2.) During the 1980s, Federal financing of R&D performed by industry increased at an average annual rate of 5 percent; however, this growth rate has slowed to less than 2 percent per year since 1985 (in constant 1982 dollars). Most of the strong growth in Federal Government support for R&D in industry during the past decade was accounted for by the Federal defense budget (discussed further below).

Total Federal expenditures for R&D reached an estimated $63 billion in 1989. (See text table 4-1.) Of this,

- 52 percent was transferred to industry,
- 25 percent was disbursed to various Federal agencies,
- 14 percent to universities and colleges,
- 8 percent to federally funded research and development centers (FFRDC), and
- 1 percent to nonprofit institutions. (See appendix table 4-2.)

The third largest R&D-performing sector consists of the Nation's universities and colleges.[4] These institutions depended on Federal funds for an estimated 59 percent of their R&D activities in 1989; this is down from 67 percent

Text table 4-1. U.S. R&D funders and performers: 1989

Funders			Performers		
	Millions of dollars	Percent		Millions of dollars	Percent
Industry	64,035	48	Industry	95,350	72
Federal Government	62,700	47	Federal Government	14,750	11
Universities and colleges	3,800	3	Universities and colleges	13,900	11
			FFRDCs	4,650	4
Nonprofits	1,815	1	Nonprofits	3,700	3
Totals	132,350	100		132,350	100

Notes: Data are estimates. See footnotes appendix table 4-2.

See appendix table 4-2.

Science & Engineering Indicators—1989

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[4] One hundred universities account for about 85 percent of the R&D performed by this sector. The research activities of these institutions are discussed more fully in chapter 5.

Definitions

The National Science Foundation (NSF) uses the following definitions in its resource surveys.

Basic research: Basic research has as its objective a fuller knowledge or understanding of the subject under study, rather than a practical application thereof. As applied to the industrial sector, basic research is defined as research that advances scientific knowledge but does not have specific commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company.

Applied research: Applied research is directed toward gaining knowledge or understanding necessary for determining the means by which a recognized and specific need may be met. In industry, applied research includes investigations directed to the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes.

Development: Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes.

Obligations: Obligations represent the amounts for orders placed, contracts awarded, services received, and similar transactions during a given period, regardless of when the funds were appropriated or when payment is required.

in 1980. (See appendix table 4-2.) Academic institutions themselves finance a larger proportion of their R&D—from 22 percent in 1980 to an estimated 27 percent in 1989. Similarly, transfers from industry to universities and colleges have increased over the same period—from 4 percent to 7 percent of the total R&D performed in these institutions.[5]

BASIC RESEARCH, APPLIED RESEARCH, AND DEVELOPMENT

Each of the sectors fund and perform basic research, applied research, and development to varying degrees. (See "Definitions," this page.) Different sectors dominate in these R&D work categories:

- Industry in both *funding* and *performing* development and applied research,
- The Federal Government in *funding* basic research, and
- Research universities in *performing* basic research.

The following sections discuss patterns and emphases by character of work among these sectors and other funders and performers of R&D.

Broad National Patterns

While the Nation's total investment in R&D has grown significantly, the relative emphasis of this investment among basic and applied research and development has changed hardly at all. Since 1960, the proportions of total R&D devoted to these types of activities have shifted only marginally:

- Development has fluctuated between 63 percent and 69 percent;
- Applied research, between 21 percent and 24 percent; and
- Basic research, between 9 percent and 14 percent. (See appendix tables 4-2, 4-3, 4-4, and 4-5.)

In 1989, private firms performed 85 percent of *development*, followed by Federal in-house laboratories, which performed 11 percent. (See figure 4-2.) Firms also performed most of the *applied* work (72 percent); the academic sector and Federal in-house laboratories were each responsible for 12 percent of the total. Half of the *basic* research was performed by universities and colleges; of the remainder, 18 percent was conducted by firms, and 12 percent each by in-house Federal Government laboratories and FFRDCs.

Federal Obligations for R&D

Federal R&D funding patterns since 1980 clearly reflect government investment priorities. Development grew by 52 percent (in constant dollars), mainly due to defense-related work. (See text table 4-2.) Basic research obligations (see "Definitions," this page) increased 44 percent, exemplifying continued commitment to a strong Federal role in this area. Federally funded applied research has declined 7 percent during the decade. This adheres to stated policy that private industry can—except in national defense and space-related programs—respond to market forces better than the Federal Government in making R&D investment decisions.[6]

Patterns of Federal Agency Support. Federal obligations data collected from agency budgets reveal (1) the relative emphases of the character of work supported by the different agencies, and (2) the specialized relationships that have developed over the years between the agencies and the actual performers of the R&D. The data also show

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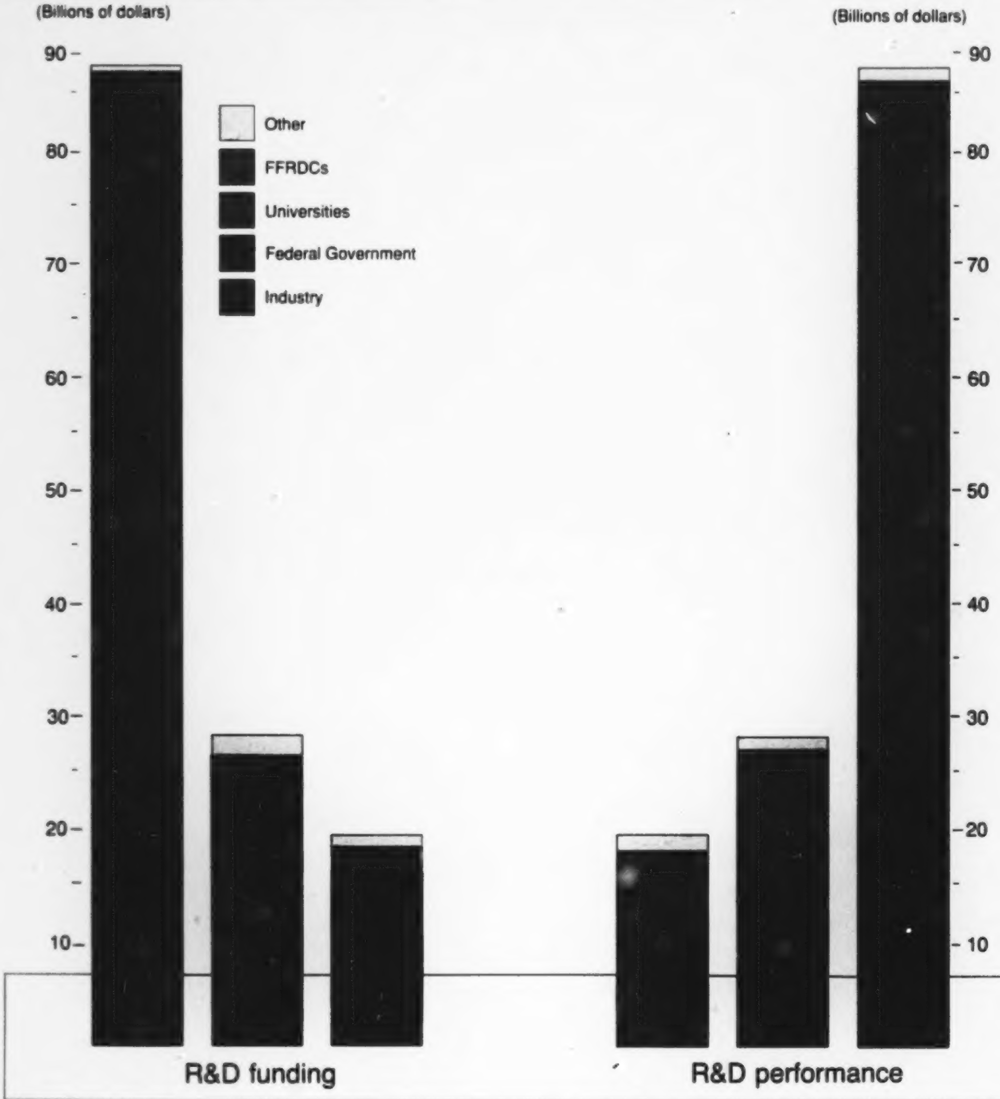
[5] The growing transfer of funds for R&D from industrial firms to universities and colleges is discussed more fully in chapter 5.

[6] See also Office of Science and Technology Policy (1989).

Figure 4-2.
National R&D, by funding and performing sectors and character of work: 1989



Development	Applied research (Billions of dollars)	Basic research		Basic research	Applied research (Billions of dollars)	Development
0.6	1.8	1.0	Other	1.4	1.1	1.2
-	-	-	FFRDCs	2.3	1.0	1.4
-	-	2.3	Universities	9.5	3.5	0.9
39.6	11.1	12.0	Federal Government	2.3	3.5	8.9
46.3	14.5	3.3	Industry	3.2	18.2	74.0

Notes: See footnotes to appendix table 4-3. All data are estimates.
See appendix tables 4-2, 4-3, 4-4, and 4-5.

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Text table 4-2. Federal obligations for defense and nondefense R&D, by character of work: 1980-89

	1980	1989	Percent change
	Billions of constant 1982 dollars		
Total R&D	35.2	47.7	36
Basic research	5.5	8.1	47
Applied research	8.2	7.4	-10
Development	21.5	32.1	49
Defense R&D	16.5	29.7	80
Basic research	0.6	0.7	17
Applied research	2.0	1.9	-5
Development	13.8	27.0	96
Nondefense R&D	18.7	18.1	-3
Basic research	4.9	7.4	51
Applied research	6.1	5.5	-10
Development	7.7	5.1	-34

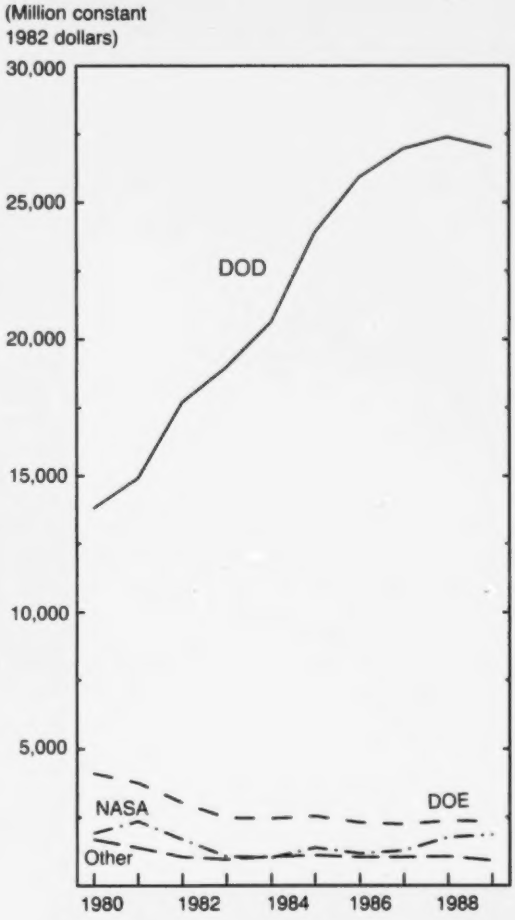
Note: Data for 1989 are estimates.

See appendix table 4-13.

Science & Engineering Indicators—1989

Figure 4-3.

Federal obligations for development, by agency: 1980-89



See appendix table 4-6.

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that, over time, Federal support for R&D activities is becoming increasingly concentrated in fewer agencies.

The Department of Defense (DOD) dominated Federal support of developmental work, accounting in 1989 for 84 percent of these Federal obligations. (See figure 4-3.) Obligations of the National Aeronautics and Space Administration (NASA) and the Department of Energy (DOE) provided most of the remainder of this category of Federal support (6 percent and 7 percent, respectively). Development supported by all other agencies (3 percent) has declined absolutely over the decade. (See appendix table 4-6.)

Federal support of applied research is less concentrated across the agencies than is development. (See figure 4-4.) DOD obligated $2.4 billion for applied research in 1989, or 26 percent of the total; the National Institutes of Health (NIH) accounted for 19 percent; DOE, 10 percent; and NASA, 18 percent. Together, these four agencies obligated 67 percent of total Federal obligations for applied research in 1980 and 73 percent in 1989. (See appendix table 4-6.)

NIH accounted for the bulk—38 percent—of total Federal support of basic research in 1989, followed by NSF, 17 percent; NASA, 13 percent; DOE, 12 percent; DOD, 9 percent; and the Department of Agriculture (USDA), 5 percent. (See figure 4-4.) The six agencies accounted for 93 percent of Federal obligations for basic research in 1980 and 95 percent in 1989. (See appendix table 4-6.)

Federal Intramural Laboratories. Overall, Federal agencies perform 24 percent of the R&D indicated by their budgetary obligations.[7] In 1989, these in-house R&D activities were estimated to cost nearly $15 billion.[8] (See appendix table 4-7.) Obligations to federally run laboratories have increased annually, on the average, by 2.8 percent for basic research and 4.7 percent for development since 1980, though since 1985 this growth has slowed considerably. Between 1988 and 1989, only NASA experienced a positive growth (in constant dollars) in intramural basic research funding. (See appendix table 4-8.)[9]

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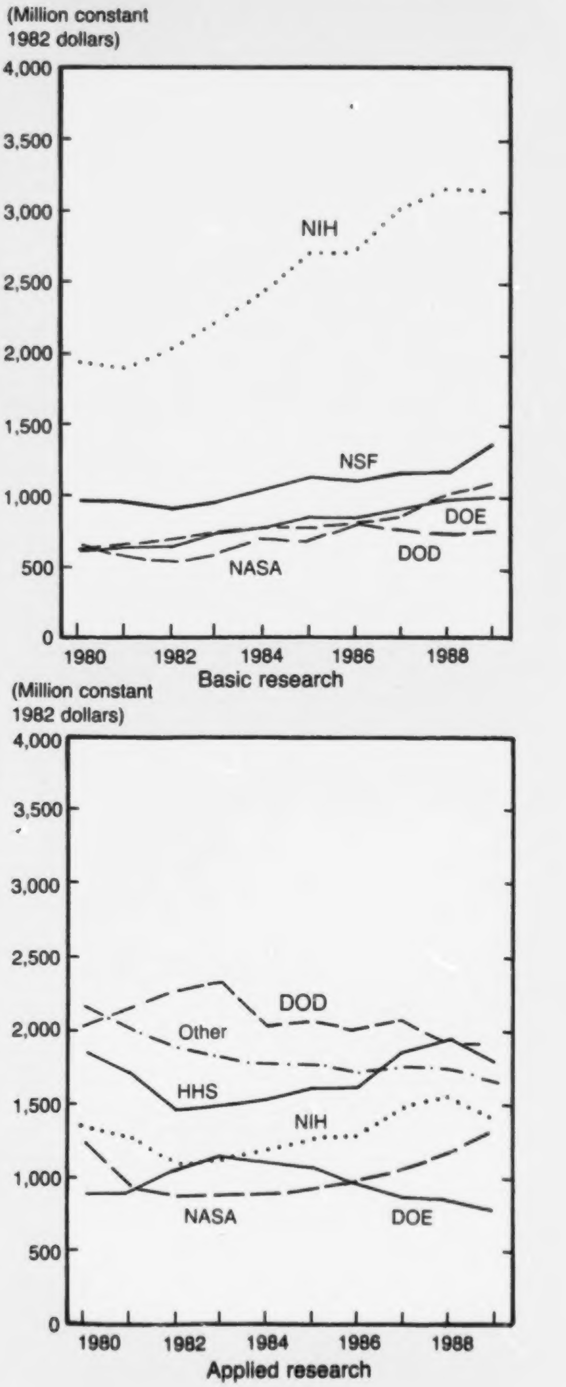
[7] All intramural obligations data include administrative costs of the R&D programs.

[8] Transfers among Federal agencies are included in these data, but are not identified separately here.

[9] Appendix table 4-8 shows an increase for intramural research by the National Science Foundation. However, NSF may not, by law, operate laboratories. NSF intramural funding includes transfers to other agencies, especially to the Department of the Navy for support of NSF Antarctic programs.

Figure 4-4.
Federal obligations for research, by agency: 1980-89



See appendix table 4-6. *Science & Engineering Indicators—1989*

Federal agency expenditures on basic research performed in-house were estimated at $2 billion. NIH supports most of its in-house basic research at its laboratories in Bethesda, Maryland. In 1989, this activity cost about $630 million; this was 16 percent of NIH's basic research budget and 28 percent of the Federal total for intramural basic research. (See appendix table 4-9.) The other two significant funders and performers of intramural basic research are NASA (22 percent of the total in 1989) and USDA (15 percent). The Department of Defense financed 12 percent—or $278 million—of the Federal Government's in-house basic research in 1989, but this was a decrease both in deflated dollars since 1984 ($303 million) and relative to other agency shares. (See appendix table 4-8.)

Federal intramural laboratories in 1989 performed over five times more applied research and development than basic research—$12.5 billion versus $2.3 billion. (See appendix table 4-9.) DOD and NASA, for example, together accounted for 75 percent of total Federal obligations for in-house R&D; and most (69 percent) of this was for applied research and development. Laboratories operated by Federal agencies are overwhelmingly devoted to knowledge discovery or application focusing on the Nation's defense and space policies.

A significant portion (40 percent) of the Federal intramural applied research total is provided by a group of smaller, specialized agencies with important R&D missions. (See appendix table 4-9.) The contributions of these agencies' in-house R&D tends to be obscured by the relatively large R&D intramural obligations of DOD, NIH, and NASA. These smaller agencies and programs include:

- The Agricultural Research Service and Cooperative State Research Service of USDA,
- The Geological Survey of the Department of the Interior,
- The National Oceanographic and Atmospheric Administration of the Department of Commerce, and
- Medical sciences research in the Veterans Administration.

Distinctive R&D Agency-Performer Patterns. Distinctive patterns of support among Federal funding agencies and different types of R&D performers have developed over the years. For example, total Federal R&D obligations to FFRDCs is dominated by funding from DOE and DOD. (See text table 4-3.) Likewise, DOD, NASA, and DOE maintain ongoing specialized relationships for applied research with industrial firms and FFRDCs administered by either universities, industry, or nonprofit institutions. NIH, in contrast, expends the bulk of its applied research and development funds at nonprofit institutes and the research hospitals of the academic sector.

As for basic research, different agencies and different performing sectors play relatively larger roles than in applied research and development. The largest performer of basic research (in terms of total agency basic research obligations) is universities and colleges (52 percent); this sector is primarily funded by NIH (50 percent), NSF (24 percent), and DOD (10 percent). DOE, as in its support of

Text table 4-3: Federal R&D obligations, by agency and performing sector: 1989

Performer	Performer total Federal obligations	Primary funding source		Secondary funding source	
	Millions of dollars		Percent		Percent
Total R&D					
Intramural laboratories	14,745	DOD	62	NASA	13
Industrial firms	29,184	DOD	86	NASA	8
FFRDCs admin. by industry	1,923	DOE	79	DOD	17
Universities & colleges	8,167	NIH	49	NSF	17
FFRDCs admin. by U&C	3,638	DOE	55	DOD	24
Other nonprofit institutions	1,706	NIH	51	DOD	16
FFRDCs admin. by nonprofits	528	DOD	83	DOE	14
Basic research					
Intramural laboratories	278	NIH	28	NASA	22
Industrial firms	1,267	NASA	59	DOD	15
FFRDCs admin. by industry	142	DOE	93	NIH	3
Universities & colleges	5,308	NIH	50	NSF	24
FFRDCs admin. by U&C	1,101	DOE	70	NASA	18
Other nonprofit institutions	734	NIH	73	NSF	12
FFRDCs admin. by nonprofits	15	DOE	91	DOD	6
Applied research					
Intramural laboratories	3,505	DOD	27	NASA	21
Industrial firms	2,150	DOD	47	NASA	33
FFRDCs admin. by industry	316	DOE	62	DOD	19
Universities & colleges	2,118	NIH	51	DOD	12
FFRDCs admin. by U&C	585	DOE	57	NASA	26
Other nonprofit institutions	527	NIH	49	NASA	9
FFRDCs admin. by nonprofits	73	DOE	60	DOD	20
Development					
Intramural laboratories	8,971	DOD	88	NASA	7
Industrial firms	26,374	DOD	91	NASA	5
FFRDCs admin. by industry	1,465	DOE	82	DOD	18
Universities & colleges	741	DOD	45	NIH	37
FFRDCs admin. by U&C	1,952	DOE	46	DOD	41
Other nonprofit institutions	445	DOD	47	NIH	17
FFRDCs admin. by nonprofits	441	DOD	96	DOE	4

Note: Data are estimates.

See appendix table 4-9.

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applied research and development, obligates most—84 percent, or $774 million—of its basic research funds to FFRDCs *under contract with universities*. Federal obligations for basic research in private firms are concentrated in the budgets of NASA and DOD. NASA is especially atypical in its reliance on private firms for basic research, accounting for 59 percent of that sector's total Federal basic research obligations.

Federal funding of basic research in industry has been cyclical over the long term. (See appendix table 4-10.) During the past two decades, total Federal funding of basic research in private firms declined to constant-dollar lows of $206 million in 1975 and $271 million in 1982. The overall trend in the 1980s has been positive, with Federal financing of industrial basic research increasing about 3.5 percent per year in real terms.

These recent increases have not been related to growth in DOD expenditures, however: DOD transfers to industry for basic research have actually decreased annually 3 percent during the 1980-89 decade. Rather, the increases are due to growing support for industrial basic research from NASA (3 percent per year since 1980), NIH (10 percent), DOE (15 percent), NSF (15 percent), and all other agencies (12 percent).

Field of Science and Engineering. Federal obligations for research, distributed across the broad fields of science and engineering, have generally increased in basic research and decreased in applied research over the past 10 years. (See appendix tables 4-11 and 4-12.) In basic research, only obligations for the social sciences have decreased, down about 38 percent since 1980. The environmental sciences have increased at the slowest rates: about 2 percent per year, on the average, since 1980. As a result of these annual incremental changes, the relative shares of Federal obligations to basic research in certain fields have shifted. For example, obligations in the life sciences increased from 44 percent to 47 percent of the total, those in environmental sciences dropped from 11 percent to 9 percent, and the social sciences declined from 3 percent to 1 percent.

Applied research obligated in Federal agency budgets has lost favor during the 1980s; the exceptions to this trend have been mathematics and computer science, which have grown by nearly 9 percent per year. (See appendix table 4-12.)

Federal Defense and Nondefense Obligations

Most R&D obligations of the Federal Government are for defense. In fact, in 1989, an estimated 65 percent of total Federal obligations for R&D were earmarked for this purpose. (See appendix table 4-13.) Between 1980 and 1989, Federal R&D obligations for defense increased by 80 percent. (See text table 4-2 and figure O-5 in Overview.)

Defense-related increases in federally funded R&D have been led by investments in developmental work—mainly for new weapons systems—throughout the 1980s. These investments have nearly doubled in constant dollars. Defense basic research has also experienced real growth—17 percent over the decade—but is less than 1 percent of total defense R&D.

In contrast, nondefense R&D obligations of the Federal Government display a declining pattern over the decade. A 34-percent decrease in development funding (mainly in energy-related technologies), combined with a parallel 7-percent decrease in applied work, resulted in decreased total Federal obligations for nondefense R&D of 3 percent. This decline was not offset by increases in basic research investments of 51 percent.

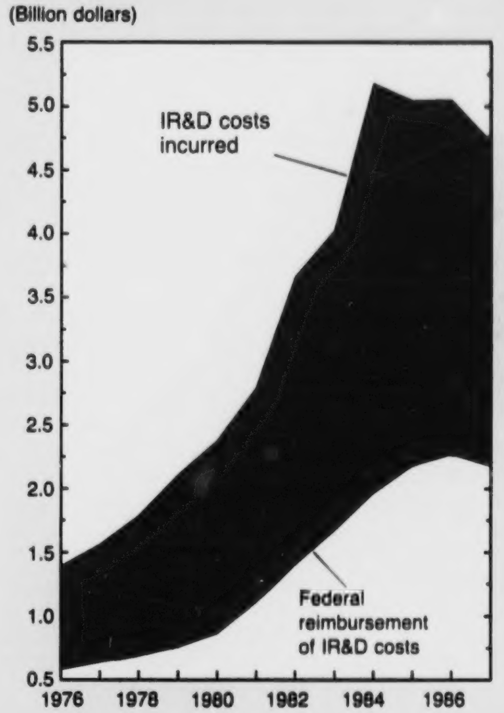
Independent Research and Development

A unique program of the Federal Government for the support of R&D is *independent research and development (IR&D)*. IR&D consists of in-house and extramural R&D carried out by private contractors on projects they themselves choose in anticipation of the Government's defense and space needs. The Federal Government allows contractors to recover a certain level of their IR&D costs as overhead charges allocated to Federal contracts (both R&D and procurement) on the same basis as general and administrative costs.[10] Only NASA and DOD are significant participants in the program.

In 1987, industrial firms were estimated to have incurred $4.7 billion in IR&D costs, of which the Government reimbursed $2.2 billion, or 46 percent. (See figure 4-5.) Negotiators for industry have successfully increased this percentage, which was about 39 percent in 1978.[11]

As a proportion of R&D support by DOD and NASA, IR&D has recently decreased. (See appendix table 4-15.) After an increasing trend earlier in this decade, reaching 11.4 percent in 1984, IR&D as a percentage of total support for industrial R&D by the two agencies had fallen to an estimated 8.5 percent in 1987. Moreover, both the absolute IR&D costs incurred by industry and the absolute amounts reimbursed by the Government turned down in 1987 over 1986. NASA's reimbursements decreased sharply in 1986 following the Challenger accident, when many NASA R&D programs were delayed.

Figure 4-5.
IR&D costs and reimbursements: 1976-87



Note: 1987 data are estimates.
See appendix table 4-14.

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[10] Following a DOD technical evaluation of company R&D plans, each major contractor negotiates an advance agreement on the size of its IR&D program. DOD negotiates for all agencies, and the negotiations result in both a ceiling for the contractor's IR&D allowable expenditures and a percentage of these costs that the Government will reimburse. Companies regularly exceed their ceilings, but may not charge these costs to government contracts.

[11] The Federal Government has encouraged industry-university cooperation by allowing higher ceilings for IR&D in firms that were able to demonstrate increased interaction with universities using IR&D. See NSB (1985), pp. 43-44.

Federal R&D Support by National Objective

The Office of Management and Budget identifies 16 budgetary categories, or "functions," that contain Federal R&D programs.[12] These are the functions in which the Federal Government has established national policy objectives as reflected in Federal spending documents.

Five functions are estimated to dominate Federal R&D obligations in 1990, accounting for 93 percent of Federal R&D obligations:

- National defense—65 percent (see "Federal Defense and Nondefense Obligations " discussion, above),
- Health—12 percent,
- Space research—9 percent,
- General science—4 percent, and
- Energy—3 percent. (See figure 4-6.)

Three other functional areas of Federal concern each account for between 1 percent and 2 percent of R&D obligations: transportation, natural resources, and agriculture.

The *nondefense* portion of Federal R&D obligations is dedicated to the functions of health (35 percent), space (26 percent), general science (11 percent), and energy (10 percent). In Federal funds for *basic research* only, health (41 percent) and general science (23 percent) predominate.[13] (See figure 4-6.)

The relative shares of Federal R&D funds devoted to these various functional areas have changed over the decade. Federal funding for energy R&D declined from 12 percent of total obligations in 1980 to 3 percent in 1990. (See appendix table 4-16.) Most of this decrease over the decade reflected Federal policy to leave applied and development work in commercial energy technologies to the private sector.

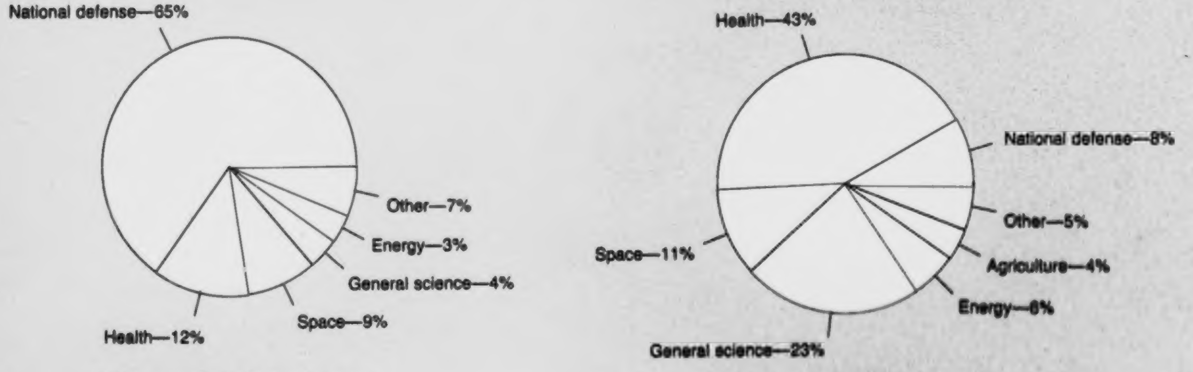
Industrial R&D[14]

Support for basic research in industry comes largely from companies' own funds; in 1986, 81 percent of basic research expenditures were estimated to have come from companies' own financial resources. (See appendix table 4-18.) The remainder came from the Federal Government. These relative shares have changed little over the past two decades.

Federal funding of industrial basic research is concentrated in two industries. In 1986, about 54 percent of all industrial receipts from the Federal Government for this work were located in the electrical equipment (Standard Industrial Classification—SIC—code 36) and transportation (SIC 37) industries, the latter of which includes aircraft and missiles. (See appendix table 4-18.) Most (52 percent) Federal support of basic research within the electrical equipment industrial group was in communication equipment firms (SIC 366), but firms' own funding dominated this industrial group.

In transportation equipment, however, the pattern was reversed. Federal funding for basic research dominated in both the group overall and in the aircraft and missiles subgroup, providing 55 percent and 65 percent, respectively, of the funding. Overall, 85 percent of all basic research in transportation was located in aircraft and

Figure 4-6.
Federal R&D funds, by budget function: 1990



Total research and development

Basic research

See appendix tables 4-16 and 4-17.

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[12] For definitional details, see NSF (1989b).

[13] By definition, virtually no applied or development work appears in the "general science" budgetary category. In contrast, health and space research each account for about 7 percent of applied and development work combined.

[14] Industrial R&D is discussed in greater detail in chapter 6.

missiles, underlining the relatively small amount of basic research (i.e., some $46 million) performed in the United States in nonaviation transportation.

Available estimates on large industry groups reflect the R&D funding patterns and missions of the Federal Government. Across all industries, the ratio of basic research to applied research to development was approximately 1:6:24. (See appendix table 4-18.) Ratios among these types of R&D work are different, however, when broken out by source of funds (Federal versus industry funds) and by large industry group. NASA's and DOD's mission funding in the aircraft and missiles group (SIC codes 372 and 376), for example, is reflected in the ratio of Federal Government funding in this industry of 1:10:66; industry's own funding ratio is 1:13:36. In all three categories of R&D work in the aircraft and missiles subgroup, Federal funding accounted for more than 50 percent of the industry's total performance in 1986.

INTERNATIONAL COMPARISONS

R&D Funding as a Percentage of GNP

R&D expenditures as a percentage of GNP has become one of the most widely used indicators of a country's commitment to scientific knowledge growth and development. The industrialized nations of France, West Germany, Japan, the United Kingdom, and the United States have maintained an R&D/GNP ratio of between 2 percent and 3 percent throughout the decade of the 1980s. Differences in emphases among these countries in the types of R&D investments become clear, however, when they are disaggregated.[15]

The funding of R&D as a percentage of GNP has increased in the major industrialized countries over the past 10 years. (See appendix table 4-19.) The approximate 2.6-percent R&D/GNP ratio of the United States has increased by at least half a percentage point (although it decreased in 1984 and 1985). (See figure O-2 in Overview.) The growth in this indicator, however, has not kept pace with the same indicator in Japan and West Germany, both of which now invest a larger percentage—2.9 percent and 2.8 percent, respectively. Both of these countries have now exceeded the U.S. on this indicator for 3 years (1985-87).

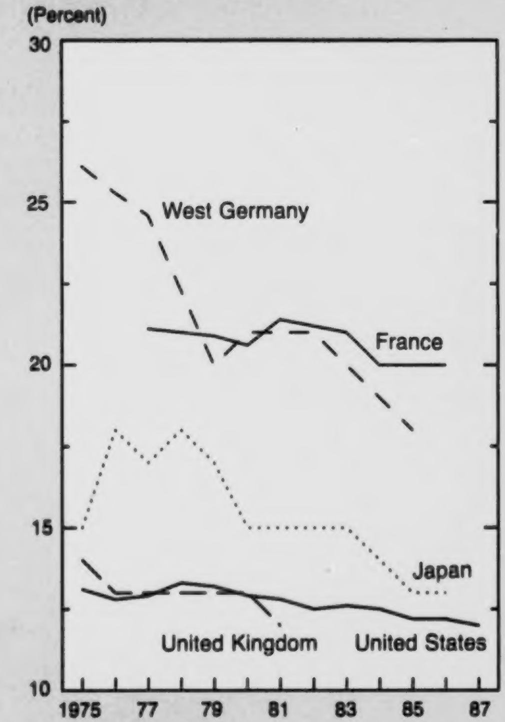
Defense and Nondefense R&D Expenditures

Nondefense R&D expenditures as a percentage of GNP in both Japan and West Germany exceeds that of the United States. The Japanese spend a full percentage point more of their GNP on nondefense R&D (see figure O-3 in Overview); West Germany spends eight-tenths of a percentage point more. Furthermore, this ratio has been growing faster during the eighties in other countries than in the United States. Between 1980 and 1987 (the last year for which comparable data are available), countries increased their nondefense R&D/GNP ratio as follows:

- U.S., from 1.7 percent to 1.8 percent;
- Japan, from 2.2 percent to 2.8 percent;
- West Germany, from 2.3 percent to 2.6 percent; and
- France, from 1.4 to 1.8 percent. (See appendix table 4-20.)

The United States spent approximately $68 billion on nondefense R&D in 1987, compared with $39 billion in Japan and $18 billion in West Germany.[16] The United Kingdom and France invested about $10 billion to $11 billion each. (See appendix table 4-20.) The growth in these investments in Japan has outstripped that in the other industrialized countries. Between 1980 and 1987, for example, Japan's nondefense R&D grew by 69 percent (in constant dollars) compared to U.S. growth of 21 percent. Comparable percentage increases were 43 percent in France and 27 percent in West Germany.

Figure 4-7.
Basic research as a percentage of total R&D



See appendix table 4-21.

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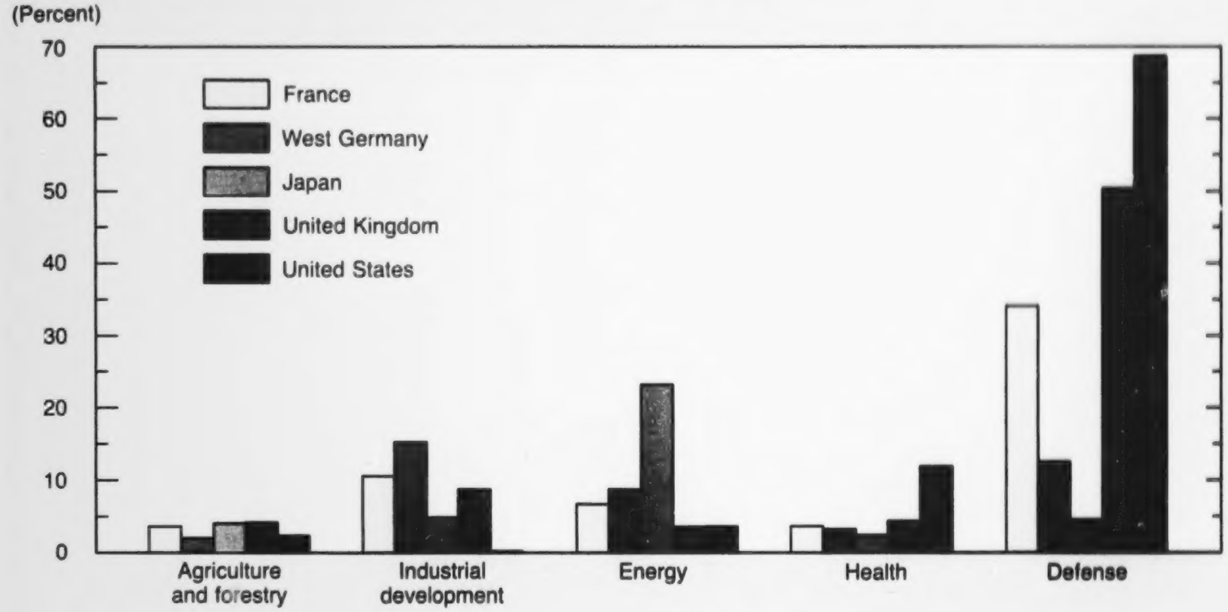
[15] Detailed and more extensive data can be found in NSF (1989c).

[16] See appendix table 4-20 for details on conversion of national currencies to dollars.

Figure 4-8.
Government budget appropriations for R&D, by socioeconomic objective: 1987



See appendix table 4-22.

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In 1987, the U.S. invested approximately $11 billion less than Japan, West Germany, the United Kingdom, and France combined in nondefense R&D. On the other hand, in total R&D *including defense*, the U.S. invested $15 billion more than these four nations combined.

Basic Research Versus Total R&D

The United States and Japan devote about the same proportion of their R&D investments to basic research: 12 percent and 13 percent, respectively, in 1986. (See figure 4-7.) France spends about one-fifth of its total R&D on basic research, compared to 18 percent (in 1985) for West Germany.

R&D by Socioeconomic Objective

The relative shares of countries' R&D appropriations reflect striking differences in areas of national interest. In the United States, 69 percent of the total Federal investment in R&D is devoted to national defense, compared to 50 percent in the United Kingdom, 34 percent in France, 13 percent in West Germany, and 5 percent in Japan. (See figure 4-8.) The United States Government also stands out for its investments in health-related R&D (12 percent); this emphasis is especially notable in R&D performed in academic and similar institutions. (See "Fields of Academic R&D" discussion, next page, and appendix table 4-22.) About 4 percent of Government appropriations for R&D in the U.S. are connected with national objectives related to energy and the general advancement of knowledge.[17]

Japanese Government appropriations for R&D are invested relatively heavily in general university research (about 50 percent for "advancement of knowledge" and "general university funds"—GUF—combined). The Japanese also spend about 23 percent of their governmental R&D funds on energy-related R&D, reflecting the country's concern with its heavy dependence on foreign sources of energy.

The Government of West Germany invests heavily in R&D related to industrial development—15 percent of its total 1987 investment versus 11 percent in France, 5 percent in Japan, and 0.2 percent in the United States. The small proportion of U.S. investments in industrial development reflects a long-standing policy of the U.S. Government to rely on private sector investment decisions in this area.

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[17] In the U.S., "advancement of knowledge" is a catch-all budgetary category for basic research unrelated to a specific national objective. "General university funds," which contain some basic research funds, cannot be separately distinguished in the United States. See, however, the "Fields of Academic R&D" discussion, next page, and Martin, Irvine, and Isard (forthcoming).

Fields of Academic R&D

Differences in R&D-performing institutions, and different institutional accounting practices, confound efforts to compare different countries' R&D investments and emphases. This is particularly true in the case of academic R&D, which comprises hundreds of different accounting systems.

A recent analysis performed at the Science Policy Research Unit (SPRU) in Sussex, England, and jointly sponsored by NSF and Britain's Advisory Board for the Research Councils permits international comparisons—by field—of academic and academically related research (Martin, Irvine, and Isard, forthcoming). These research activities are closely tied to the growth of disciplinary public knowledge commonly published in the scientific literature. Because it plays such an important role in social and economic progress, the growth of such knowledge is widely viewed as critical in national R&D investment strategies.

In the United States, a particularly thorny problem in collecting data on academic R&D concerns general university funds (GUF). U.S. universities have been increasing their own funding of R&D, but what proportion of these GUF funds support R&D? The data describing university support for R&D elsewhere in this chapter do not include GUF that support R&D *and* are not identified by the universities as support for specific research projects. (See appendix tables 4-2 and 4-5.) This issue arises particularly in the case of public universities, which receive general appropriations from state governments and then distribute them among different activities, including some research activities.

The SPRU analysts produced an estimate of support for academic research otherwise subsumed in GUF as follows. Using the percentage of work time that faculty spend on research, they calculated a "faculty-salary" contribution in GUF. This GUF contribution to academic research support involved multiplying the number of faculty in public universities by a coefficient derived from the percentage of time academic faculty spend on research, and multiplying the resulting "research full-time equivalent personnel" by average 9-month salaries, including fringe benefits. To generate broad field estimates, the analysts then distributed their total estimate across fields according to the distribution of academic staff in the different fields. Thus, in the SPRU analysis, academic R&D financed by university funds consists of the GUF faculty-salary contribution, plus other institutional funds set aside specifically for research.

The U.S. academic and academically related R&D support in figure 4-9 and appendix table 4-23 thus consists of three parts. (Details of the equivalent numbers for other countries can be found in Martin, Irvine, and Isard, forthcoming.)

1. *University support for research:*
   - Institutions' own funds set aside specifically for research, and
   - The GUF contribution discussed above.
2. *Separately budgeted academic research:*
   - Federal, state, and local current and capital R&D expenditures on campuses;
   - Federally financed fellowships; and
   - An estimate of project management costs borne by the Federal funding agency.
3. *Academically related research:*
   - Activities of the 19 FFRDCs administered by universities (in 1987) that relate to provision of central facilities for academic researchers, and
   - Intramural research of the NIH. For other countries in the analysis, this last category includes research council establishments of the type common in European countries, as well as various agricultural and medical institutes, especially those with a role in postgraduate training. Examples include the Max-Planck Institutes in West Germany and laboratories of France's *Centre National de la Recherche Scientifique* (CNRS).

STATE-LEVEL SUPPORT FOR SCIENCE AND TECHNOLOGY[18]

Indicators of recent increased state-level support for science and technology are of two types:

- New organizations in state governments established specifically for the development of science and technology, and
- Increased state funding for S&T-related activities, including R&D.

The following sections present data and analysis from a recent survey of the state S&T agencies in 13 states, and state R&D expenditure data from a special national survey.

History

In recent years, much publicity has accompanied the creation of new state S&T programs designed to enhance the states' technological and competitive capacities. The history of state programs supporting S&T can be divided into three periods characterized by particular underlying economic, sociological, and political forces.

From the Morrill Act to 1980. The *first phase* in the relationship between states and S&T began when President

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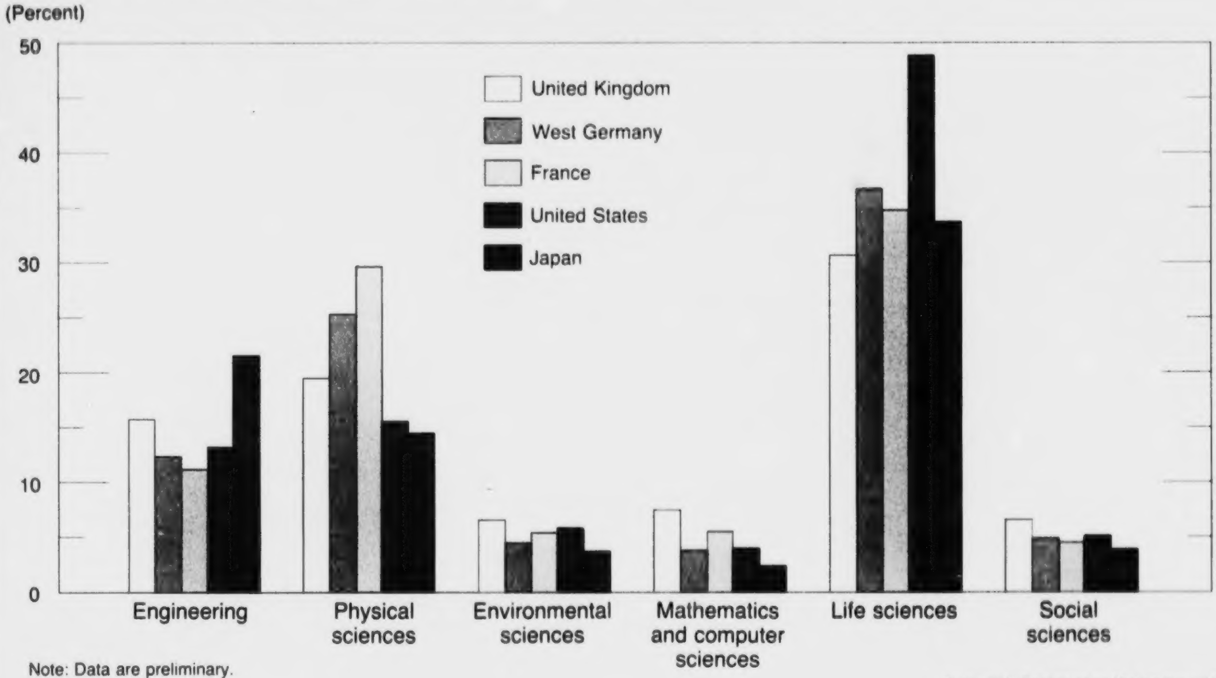
[18] "S&T" is used in this section to emphasize the broad range of state activities in the support of economic development based on science and technology.

The SPRU analysis shows that all of the countries emphasize the life sciences in their academic research, with the U.S. devoting almost half its academic support in this broad field. (See figure 4-9.) The U.S. also stands out in its investment of larger absolute amounts of financial resources across all broad S/E fields. (See appendix table 4-23.)

France emphasizes the physical sciences, investing 30 percent of its total academic R&D. Other European countries also invest more in the physical sciences relative to the United States and Japan. The Japanese stand out in their relatively strong support of academic R&D in engineering, though the U.S. spends absolutely more than twice as much as Japan in this category.

Figure 4-9.
Academic and academically related research, by field and country: 1987



Note: Data are preliminary.
See appendix table 4-23.

Science & Engineering Indicators—1989

Lincoln signed legislation establishing the U.S. Department of Agriculture. In 1862, the Morrill Act granted the states Federal land for the establishment of what later became known as the "land grant" colleges and universities. Since then, virtually all states have been active in the support of new knowledge development in agriculture and the dissemination of this knowledge to agricultural users. The Federal Government contributed to this institutionalization through:

- USDA's Agricultural Research Service, with its network of research facilities throughout the Nation;
- The Cooperative State Research Service; and
- The Agricultural Extension Services.

With the expansion of the land grant universities, a model evolved for cooperation of the Federal, state, university, and industry sectors in the support of S&T-based economic development.

A *second phase* for state S&T interests was initiated shortly after World War II, when existing programs were eclipsed by the rapid growth of Federal S&T programs and agencies. Federal support of science and technology—especially for defense, space, and health-related objectives—had considerable impact on states and regions. Federal funds for research and the education of veterans contributed to the very rapid growth of institutions of higher education, and some schools began to emerge as significant national research institutions. Regional institutions, including technical institutes and most land grant schools, expanded their engineering programs. They also frequently developed special relationships with local industries. Organized research units proliferated on campuses, separated from traditional disciplinary departments.[19] These new research units usually had a more applied orientation than the academic departments.

Industries—particularly those performing defense and space work—were attracted to the supply of talent at universities or at specialized government installations (e.g., California, Texas, and Florida for space programs; California, Massachusetts, and Washington for defense programs). By locating businesses in these areas, concentrations of regional development emerged. At least one state, North Carolina (which established its Board of Science and Technology in 1963), explicitly intended to recreate the conditions underlying other regional development patterns by capitalizing on a network of public and private universities around Chapel Hill in what has become known as the "Research Triangle." Thus, a state's strong tradition of public support for education was channeled into an outright effort to bring together in one region the academic expertise of several universities for the purpose of high-tech development.

Concurrently, a brief flurry of state activities in support of S&T occurred in the 1960s. Under the State Technical Services Program of the U.S. Department of Commerce, some states created S&T commissions and foundations, and some appointed science advisors to the governor. In the 1970s, NSF, through its Intergovernmental Science and Technology Program, supported the formation of organizations to provide S&T information to state governments. It also helped to establish state S&T advisors and boards, which were often located in legislative branches. Although a few of these offices survive, they are separate from the new, action-oriented institutions discussed below, most of which are executive branch agencies and some of which are in the governor's office itself.

The 1980s. A *third phase* in state support for S&T started in the early 1980s.[20] States began establishing agencies to promote S&T development, and by 1988 at least 38 states had such offices.[21]

Several factors underlie this growth of state-level institutions for S&T. First, economic dislocations in some states forced them to search for models for economic growth based on S&T. For example, some states in the Midwest and Northeast faced declines in their traditional "smokestack" industries and turned their attention to an existing resource—research universities—as the centerpiece of new economic development policies. This practice was aimed at:

- Creating and attracting knowledge-intensive industries to replace those declining because of new technologies, reduced markets, or foreign competition; and
- Encouraging modernization by existing but troubled manufacturing industries.

Similarly, oil-producing states like Texas, Oklahoma, and Alaska—which experienced severe economic declines when oil prices dropped—also enacted S&T-promoting agencies and programs. These initiatives were usually undertaken in the executive branch, and often figured prominently in gubernatorial contests. In fact, the National Governors' Association itself has played a significant role in promoting the awareness of the S&T role in economic development.[22]

Second, the new state initiatives reflected changes in the Federal approach to science investments. Some new Federal programs began to require state and/or industrial matching funds. States were also keenly aware of the size of some large new scientific and technological enterprises—e.g., DOD's Sematech (a consortium to develop manufacturing technologies) and the Microelectronics and Computer Technology Corporation (MCC) both now located in Texas—and the need for coordinated efforts involving state, industrial, and university resources in competing for such initiatives. Announcement by the Federal Government of the Superconducting Super Collider (SSC) project also galvanized the interest of many states.

Third, changes in the nature of S/E research required not only the construction of very large scientific instruments but also new institutional forms for cross-disciplinary work. And these changes inevitably brought greater political attention to how these awards were made. In efforts to build capabilities for S&T in specific institutions—and as a result of intense lobbying by universities themselves—the U.S. Congress began inserting specific line items for research facilities in appropriations bills.[23]

New Institutional Developments

State agencies for S&T-based economic development, although they vary greatly in scope, budget, and influence, share one common characteristic: their objective is the support of S&T for economic development, and not the support of research for its own sake.

Among the 13 state S&T agencies studied,[24] agency funding varied from a low of $78,000 in Texas (FY 1988) to a high of $36 million in Pennsylvania (FY 1987). (See appendix table 4-24.) In addition to state budgetary obligations, most state agencies operate programs that require matching funds from the participating institution or business.

Level of funding, however, depends upon whether the agencies operate programs or are only advisory. State agencies with programmatic responsibilities tend to have larger budgets. Of the 13 studied, 2 state agencies have only advisory roles (Texas's Office of Advanced Technology and North Carolina's Board of S&T), and their budgets are relatively low.[25]

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[19] NSB (1985), pp. 109 and 282.

[20] This and the following sections rely heavily on Lambright, Price, and Teich (forthcoming). The study focused on "showcase" state agencies in 13 states responsible for promotion of S&T, and not on all agencies within a state with S&T-related missions.

[21] National Governors' Association (1988).

[22] See National Governors' Association and the Conference Board (1987). For a discussion of the political reasons for establishing these programs, see Feller (1984).

[23] See Savage (1989).

[24] Lambright, Price, and Teich (forthcoming).

Four of the thirteen states use the agency director as the science advisor to the governor, though this function can be unofficial (as in Arkansas) or can change from one governor to the next (as in Florida). All agencies receive advice and direction from boards of directors; in this way, board members from the business and academic communities are expected to bring their particular interests to bear on agency programs.

Some states have targeted their agency programs to have regional effects. Massachusetts, for example, has sponsored centers for R&D at regional universities and institutes of technology away from Boston; Pennsylvania established four regional offices to operate its Ben Franklin Partnership; and New York has distributed its Centers for Advanced Technology around the state.

State S&T agencies are in different stages of development. For example, although both Alaska and California established their state offices for S&T development in 1988, Alaska has embarked on a program of "capacity building" for its state S&T; California, on the other hand, is a highly developed state in terms of science and technology.[26]

While most of these agencies are relatively new, roles in the older ones have evolved. The New York S&T Foundation, for example, founded in 1963, has evolved into an important agency with a staff of 26 and sponsoring $14 million in R&D support out of a budget total of $24 million in 1987. (See appendix tables 4-24 and 4-25.) North Carolina's Board originally sponsored research centers and then spun them off to other agencies, but recently has ended its grants program.

The agencies also support S&T activities other than R&D. Six of the thirteen provided funds for purchase of scientific equipment or construction of facilities, and nine sponsored technology transfer programs. (See appendix table 4-25.) One of the more novel forms these non-R&D programs may take is the provision of venture or "seed" capital for company start-ups, sometimes using state pension funds: 7 of the 13 states provided some kind of business start-up support. Other more strictly business-oriented programs include support for incubators, assistance in qualifying for Small Business Innovation Research programs of the Federal Government, managerial and technical assistance, and establishment of research parks. Some states also have special tax incentives for S&T-related business development.

Funds for R&D by State

Two sources of data on state support of R&D (as opposed to broader *S&T* activities) are available for the 50 states, i.e.:

- An annual survey of expenditures for R&D by academic institutions, and
- A survey of state agency R&D expenditures.

Although they overlap to an unknown extent and use different methodologies, both of these indicators show growth in state support of R&D. Data on support for academic R&D also show increasing support by industry for R&D performed on the Nation's campuses, one of the goals of states' S&T policies.[27]

Academic R&D. In the annual survey of expenditures for R&D by academic institutions, university offices of research administration report the source and amount of support for separately budgeted R&D performed on their

Text table 4-4. Change in academic R&D funded by industry, by state: 1978-87

	Academic R&D funded by industry		Change in state total percentage
Rank/state	1978	1987	1978-87
	(Percent)		
	(a)	(b)	(b - a)
1 New Mexico	6.4	15.8	9.4
2 Idaho	3.5	11.7	8.2
3 Vermont	1.1	9.1	8.1
4 Missouri	1.8	9.2	7.4
5 Rhode Island	1.7	8.2	6.5
6 Washington	3.5	9.0	5.5
7 Alabama	1.8	7.1	5.4
8 Maine	6.8	12.1	5.3
9 Georgia	5.3	10.4	5.0
10 Arkansas	3.0	8.0	5.0
11 Nevada	9.8	14.5	4.7
12 Florida	3.6	8.2	4.7
13 Montana	6.0	10.6	4.6
14 Mississippi	2.7	7.2	4.6
15 Massachusetts	4.1	8.3	4.2
16 Pennsylvania	5.9	10.1	4.2
17 California	0.8	4.7	3.9
18 Indiana	5.3	9.1	3.8
19 Texas	2.7	5.7	3.0
20 Tennessee	6.6	9.6	3.0
21 North Carolina	4.6	7.6	3.0
22 Kansas	2.9	5.8	2.9
Average of all states	3.7	6.4	2.7

See appendix table 4-26.

Science & Engineering Indicators—1989

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[25] Both Texas and North Carolina also have other agencies with operating funds. Texas only recently established a separate grants program after long years of opposition to such a centralized bureau. See Texas Higher Education Coordinating Board (1988).

[26] See Alaska Science and Technology Foundation (1989). Lambright, Price, and Teich (forthcoming) report that the California office was established at least partly in response to the state's having lost out on several national awards and competitions, including the NSF-sponsored Earthquake Research Center, DOD's Sematech, and DOE's Superconducting Super Collider.

[27] See also chapter 5, pp. 110-111.

campuses. Doctorate-granting institutions reported about $1 billion of support for R&D from state and local sources in 1987. (See appendix table 4-27.)

These same data broken out by state reflect differing state resource patterns and show the effects of different institutional mixes in individual states. Eleven states account for over 50 percent of total national academic R&D expenditures from state and local sources.[28] (See appendix table 4-27.) These sources in Texas, with a strong tradition of direct funding of institutional activities, account for 11 percent of the state's total academic R&D and 9 percent of the national total of these funds. In contrast, in California—whose total academic R&D expenditure is nearly twice that of Texas—state and local sources accounted for only 2.4 percent of the state's academic R&D performed in 1987, reflecting the large Federal funding and the presence of large private research universities in that state which were less likely to receive state funding for R&D. Pennsylvania also ranks relatively low on this measure.

Insofar as state S&T policy objectives include encouragement of university-industry interactions, industry support of university R&D may serve as one indicator of the success of those policies.[29] For all states combined, industrial sources of support for academic R&D have grown faster than all other sources of support, increasing 179 percent in constant dollars from 1978 to 1987. (See appendix table 4-27.) As a percentage of total R&D support on all of the Nation's doctorate-granting campuses, industry sources of support increased from 4 percent to over 6 percent. (See text table 4-4.) Some states experienced notably larger increases in the proportion of their academic R&D from industrial sources. Many of these are states that rank low on total academic R&D expenditures, though greater than average increases have also occurred in several of the largest academic R&D-performing states, including Pennsylvania, Massachusetts, and Washington.[30]

State Agency R&D Expenditures. NSF recently resurveyed state agency R&D expenditures. (See appendix table 4-27.) To ensure comparability with a similar survey conducted in 1977, the survey of 1987 and 1988 expenditures excluded academic R&D expenditures. (However, some portion of the reported state agency expenditures may be assumed to have gone to academic institutions.)

Like the data reported above, total state agency expenditures for R&D from state sources of funds have increased overall, doubling between 1977 and 1988 to about $600 million (in constant dollars). States varied widely on this indicator, with some states reporting declines in real dollars. As noted earlier in this section, a state's political culture and history influence its reliance on state agencies to disburse R&D funds: some states appropriate most funds directly to institutions themselves, and this source of support for R&D is not reflected in these data.

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[28] These data show only state and local government sources of funds that are separately budgeted for specific projects. General university funds (GUF) used for academic R&D purposes are not included here.

[29] See "Industrial Support of R&D at Specific Academic Institutions" discussion in chapter 5.

[30] Within states, however, individual institutions often account for much of the movement of these indicators.

REFERENCES

Alaska Science and Technology Foundation. 1989. *Annual Report 1988*. Anchorage: Alaska Science and Technology Foundation.

Battelle Memorial Institute. 1987. *Probable Levels of R&D Expenditures in 1988*. Columbus, OH: Battelle.

Bradley, R., and J. Rees. 1987. "Science Policy: The Appropriate State and Federal Roles." Working Paper on Science Policy. Washington, DC: National Science Foundation, Division of Policy Research and Analysis.

Cordes, C. "Colleges Received About $289-Million in Earmarked Funds." 1989. *The Chronicle of Higher Education* 35, no. 21 (1 February): 1, A21-22.

Feller, I. 1984. "Political and Administrative Aspects of State High Technology Programs." *Policy Studies Review* 3, no. 3-4 (May): 460-66.

Government-University-Industry Research Roundtable, National Governors' Association, National Governors' Association, and National Research Council. 1987. *State Government Strategies for Self-Assessment of Science and Technology Programs for Economic Development*. A Report of a Workshop. Washington, DC: National Academy Press.

Graves, S.B. 1989. "Long Run Patterns of Corporate R&D Expenditure." *Technological Forecasting and Social Change* 35: 13-27.

Jones, B. 1986. *State Technology Programs in the United States*. St. Paul: The Governor's Office of Science and Technology Development.

Lambright, W.H., E.M. Price, and A.H. Teich. Forthcoming. *State S&T Indicators: An Exploratory Profile and Analysis*. A final report to the Science Indicators Group, National Science Foundation. Syracuse: Science and Technology Policy Center.

Martin, B.R., J. Irvine, and P. Isard. Forthcoming. *International Trends in Government Funding of Academic and Related Research*. Sussex, England: Science Policy Research Unit.

Minnesota Office of Science and Technology, Department of Trade and Economic Development. 1989. *State Technology Programs in the United States, 1988*. St. Paul: Minnesota Office of Science and Technology.

Narin, F., and J.D. Frame. 1989. "The Growth of Japanese Science and Technology." *Science* 245 (11 August): 600-05.

National Governors' Association. 1988. "The Structure and Function of State S&T Offices." *Capital Ideas* (September 1).

National Governors' Association and The Conference Board. 1987. *The Role of Science and Technology in Economic Competitiveness*. Washington, DC: National Governors' Association.

National Science Board (NSB). 1987. *Science & Engineering Indicators—1987*. NSB 87-1. Washington, DC: Government Printing Office.

———. 1985. *Science Indicators/The 1985 Report*. NSB 85-1. Washington, DC: Government Printing Office.

———. 1982. *University-Industry Research Relationships*. Fourteenth Annual Report of the National Science Board. Washington, DC: NSF.

National Science Foundation (NSF). 1989a. *Federal Funds for Research and Development:* Fiscal Years 1987, 1988, and 1989. NSF 89-304. Washington, DC: NSF.

———. 1989b. *Federal R&D Funding by Budget Function, Fiscal Years 1988-90*. NSF 89-306. Washington, DC: NSF.

———. 1989c. *International Science and Technology Data Update 1988*. NSF 89-307. Washington, DC: NSF.

———. 1989d. *National Patterns of R&D Resources: 1989. NSF 89-308. Washington, DC: NSF.*

———. 1988a. *Academic Science/Engineering: R&D Funds, Fiscal Year 1986*. NSF 88-312. Washington, DC: NSF.

———. 1988b. *Geographic Distribution of Industrial R&D Expenditures*. NSF 88-317. Washington, DC: NSF.

———. 1979. *Research and Development in State and Local Governments, Fiscal Year 1977*. NSF 79-327. Washington, DC: NSF.

Office of Science and Technology Policy. 1989. *Science and Technology Report & Outlook*. Washington, DC: Office of Science and Technology Policy.

Office of Technology Assessment (OTA). 1984. *Technology, Innovation, and Regional Economic Development*. Background Paper #2. Washington, DC: OTA.

Rogers, E.M. 1988. "The Intellectual Foundation and History of the Agricultural Extension Model." *Knowledge: Creation, Diffusion, Utilization* 9, no. 4 (June): 492-510.

Savage, J. 1989. "The Distribution of Academic Earmarks in the Federal Government's Appropriations Bills, FY 1980-1989." Oakland, CA: Office of the President, University of California, Oakland. Mimeo.

Teich, A.H., and K.M. Gramp. 1988. *R&D in the 1980s: A Special Report*. Washington, DC: American Association for the Advancement of Science.

Texas Higher Education Coordinating Board. 1988. *Technology for a New Texas: Texas Advanced Technology Research Program*. Interim Report.

Chapter 5

Academic Research and Development: Support, Personnel, Outputs

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Academic Research and Development: Support, Personnel, Outputs

HIGHLIGHTS

Funding for Academic R&D

- *The 1980s have been a decade of rapid growth in U.S. academic research and development (R&D).* From 1980 to 1989, real growth (in constant 1982 dollars) in academic R&D expenditures averaged 4.9 percent annually; the estimated 1988-89 growth rate is 3.0 percent. Funding increased in current dollars from $6 billion in 1980 to an estimated $14 billion in 1989, reaching 10.5 percent of estimated total U.S. R&D expenditures in 1989. (See pp. 107-108.)
- *The Federal share of academic R&D support has decreased,* while the non-Federal share of academic R&D funding reached an estimated 41 percent in 1989. (See p. 108.)
- *Industry's share of academic R&D funding grew from 3.9 percent in 1980 to an estimated 6.6 percent in 1989.* While most of these funds go to the better known research universities, a number of smaller, more specialized, institutions received over 20 percent of their total R&D funding from industry in 1987. (See p. 110.)

Facilities and Instruments

- *U.S. research universities saw large increases in capital investments in science and engineering (S/E) facilities during the 1980s, with expenditures reaching $1.8 billion in 1987.* Capital expenditures for S/E plant and equipment grew 7 percent annually in constant dollars between 1980 and 1987, compared with an average annual *decrease* of 9 percent between 1970 and 1980. Growth was largely due to increased support from non-Federal sources. Numbers of instruments available for academic R&D also increased during the 1980s. (See pp. 111-113.)

Characteristics of Doctoral Researchers in Academic R&D

- *The number of doctoral scientists and engineers whose primary or secondary work activity was academic R&D reached 155,000 in 1987—a 65-percent increase over the number in 1977.* Twelve percent of the total were engineers, the same proportion as in 1977. The greatest growth rate was seen for computer/information specialists, whose numbers tripled to 3,500. Approximately one-third of the doctoral scientists and engineers are life scientists; this is the largest single group. (See p. 115.)
- *Women and minorities increased their percentages in the academic doctoral R&D workforce between 1977 and 1987, but whites still made up almost 90 percent of that workforce and white males 75 percent in 1987.* Asians were 9 percent of the S/E doctoral workforce, and other minorities less than 2 percent. The proportion of women doctorates in academic R&D increased from 10 percent to 16 percent during the decade. (See pp. 115-116.)
- *Researchers in academic institutions or industry tend to continue working in the same employment sector to a greater extent than researchers in the Federal Government or nonprofit organizations, over periods of 2 to 14 years.* Related data indicate that the largest turnover of S/E doctoral researchers into other work activities occurs during their first few years in research. (See pp. 118-119.)

S/E Publication Data

- *In 1986, U.S. authors produced 36 percent of the world scientific literature, a proportion that has remained relatively stable since 1973 in the data base used for these analyses.* The USSR, United Kingdom, and Japan were next in overall proportions of world scientific publications with 8 percent each. U.S. academic institutions produced 70 percent of the U.S. S/E literature in 1986, and about 25 percent of the world S/E literature. (See p. 120.)
- *Multi-authored papers are on the rise, suggesting that individual researchers are increasing their interactions.* More than 30 percent of papers in 1986 had four or more authors, up from 15 percent in 1973. (See p. 120.)
- *U.S. researchers are increasing their publication of S/E articles with foreign authors.* In 1986, 10.2 percent of publications with at least one U.S. author were internationally coauthored, up from 5.6 percent in 1981. (See pp. 120-121.)
- *S/E researchers from industry are increasingly coauthoring papers with U.S. university researchers, suggesting a rise in cooperation between these two sectors.* Of articles with at least one industry author, 28 percent were coauthored with a university author in 1986; this was almost double the 1976 figure. (See p. 121.)
- *Citation patterns indicate that U.S. papers on average exert more influence on foreign researchers than foreign papers exert on U.S. researchers.* (See pp. 122-123.)

Patents and Products

- *Academic institutions are patenting more frequently.* The number of university patents increased from an annual average of 492 in the early 1980s to 801 in 1988. Universities received 2.0 percent of patents awarded to U.S. inventors in 1988, more than double the 0.9-percent university share in 1978. Four biomedical patent classes accounted for one-third of all patents awarded to universities in 1988. (See pp. 123-124.)

- ***Manufacturing industries depend substantially on academic research for development of new processes and products.*** **The first empirical attempt to estimate the economic return to society from academic research found an annual social rate of return of 28 percent for the seven industries studied. (See p. 124.)**

Academic research and development (R&D) is a major part of the U.S. science and engineering (S/E) structure. It accounts for an estimated 10.5 percent of total R&D expenditures in the Nation and about half of U.S. basic research expenditures. There were 155,000 doctoral scientists and engineers in academic R&D in 1987, comprising 37 percent of the doctoral S/E workforce. Researchers in U.S. academic settings publish 70 percent of the S/E articles that U.S. researchers publish and 25 percent of the world S/E literature.

A major theme in this chapter is that academic R&D is becoming increasingly interactive. Of particular interest—given the current concern with accelerating the commercialization of university research findings—are the growing numbers and types of interactions with industry. Growth in industrial funding of academic R&D and in numbers of industry-university coauthored publications provides evidence of increased contacts.

This chapter addresses three major aspects of academic R&D:

- *Support*: sources of funding and its allocation among recipients and disciplines,
- *Personnel*: characteristics of academic doctoral researchers, and
- *Outputs*: publications, patents, and commercial use of academic research findings.

In some analyses, for example, those involving S/E publication patterns, the discussion extends beyond the U.S. academic sector to encompass other sectors and other countries.

The chapter opens with a discussion of trends in funding and support for academic R&D, particularly changes in the sources of support. The Federal Government is the major supporter of academic R&D, but a large amount of funding comes from other sources. Recent increases in funding for both facilities and instrumentation have improved these aspects of the academic R&D infrastructure, although large backlogs remain. New this year is a discussion of some of the problems faced by research libraries as already expensive S/E periodicals continue to increase in price.

Discussion about the academic R&D workforce is limited to scientists and engineers with doctoral degrees, since they are the major actors in academic science and engineering research.[1] Trends in the growth of various disciplines and in the numbers of women and minorities in academic R&D fields are addressed. The chapter includes some comparative data about doctoral scientists and engineers in nonacademic basic research. Also, for the first time in the *Science & Engineering Indicators* series, data are presented about retention rates for doctoral researchers in specific employment sectors and in research activities over time periods as long as 14 years.

As the major research output of academic R&D, publications receive detailed attention. Coauthorship data show increasing cooperation in research activities among individuals, employment sectors, and countries. Citation patterns provide information about the amount of attention that researchers from particular sectors and countries give to other researchers. As part of a new analysis of citations, the chapter includes citation data for some individual countries.

Data on another output of academic R&D—patents—show that university patenting is increasing, a finding consistent with the increasing cooperation between universities and industry. On a related topic, a recent study shows that academic R&D has contributed substantially to new commercial products and processes in some industries.

ACADEMIC RESEARCH AND DEVELOPMENT: SUPPORT[2]

In 1989, the U.S. spent an estimated $13.9 billion for R&D at academic institutions.[3] (See figure 5-1 and appendix table 5-1.) This expenditure continues a gradual 20-year trend, as rising proportions of total national R&D expenditures are allocated to academic R&D: in 1969, 8.7 percent of such expenditures went to academic R&D, compared with an estimated 10.5 percent in 1989.[4] Of 1989 academic

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[1] Chapter 3 discusses the overall S/E workforce.

[2] Data in this chapter come from several different National Science Foundation (NSF) surveys that do not always use comparable definitions or survey methodologies. For example, the survey on which the publication *Federal Support to Universities and Colleges and Selected Nonprofit Institutions* (NSF, 1988c) is based obtains information on Federal "obligations" to universities and colleges directly from Federal funding agencies. By contrast, the survey on which *Academic Science/Engineering: R&D Funds* is based (NSF, 1989c) obtains data directly from the universities and colleges on their R&D "expenditures." The results do not exactly match with Federal obligations.

For descriptions of the methodologies of these and selected other National Science Foundation surveys, see NSF (1987b).

[3] In this section, academic institutions generally comprise institutions of higher education that grant doctorates in science or engineering and/or spend at least $50,000 for separately budgeted R&D (NSF, 1989c). Federally funded research and development centers associated with universities are tallied separately; these are discussed in chapter 4.

[4] Chapter 4 discusses patterns of national R&D expenditures.

R&D expenditures, an estimated 68 percent went for basic research, 25 percent for applied research, and 6.3 percent for development.

In constant 1982 dollars, academic R&D increased an estimated 54 percent between 1980 and 1989. R&D growth during the 1985-89 period is expected to be stronger for the academic sector than for any other economic sector. However, the annual rate of growth for academic R&D in 1988-89 is estimated at 3.0 percent, down from an estimated 4.9 percent during 1980-89.[5]

Support by Sector

The Federal Government provides the majority of funds for academic R&D, but other sources have been contributing increasing proportions in recent years.[6] (See figure O-20 in Overview and appendix table 5-2.) In 1989, the Federal Government provided an estimated 59 percent of the funding for R&D performed in academic institutions; this was down considerably from 72 percent in 1969. Academic institutions that perform the R&D provide the second largest share. Over the 1969-89 period, the institutional share has grown from 10 percent to an estimated 18 percent.[7] Industry increased its share to an estimated 6.6 percent in 1989, while state and local governments supported about 8 percent of academic R&D throughout the 1980s.

Private and public universities differ in their major sources of R&D support. For public academic institutions, 34 percent of R&D funding in 1987 came from state and local funds and institutional funds; private academic institutions received only 11 percent of their funding from these sources. (See appendix table 5-3.) Between 1980 and 1987, the Federal share of support decreased for both public and private institutions, dropping from 61 percent to 53 percent (public institutions) and from 79 percent to 74 percent (private institutions).

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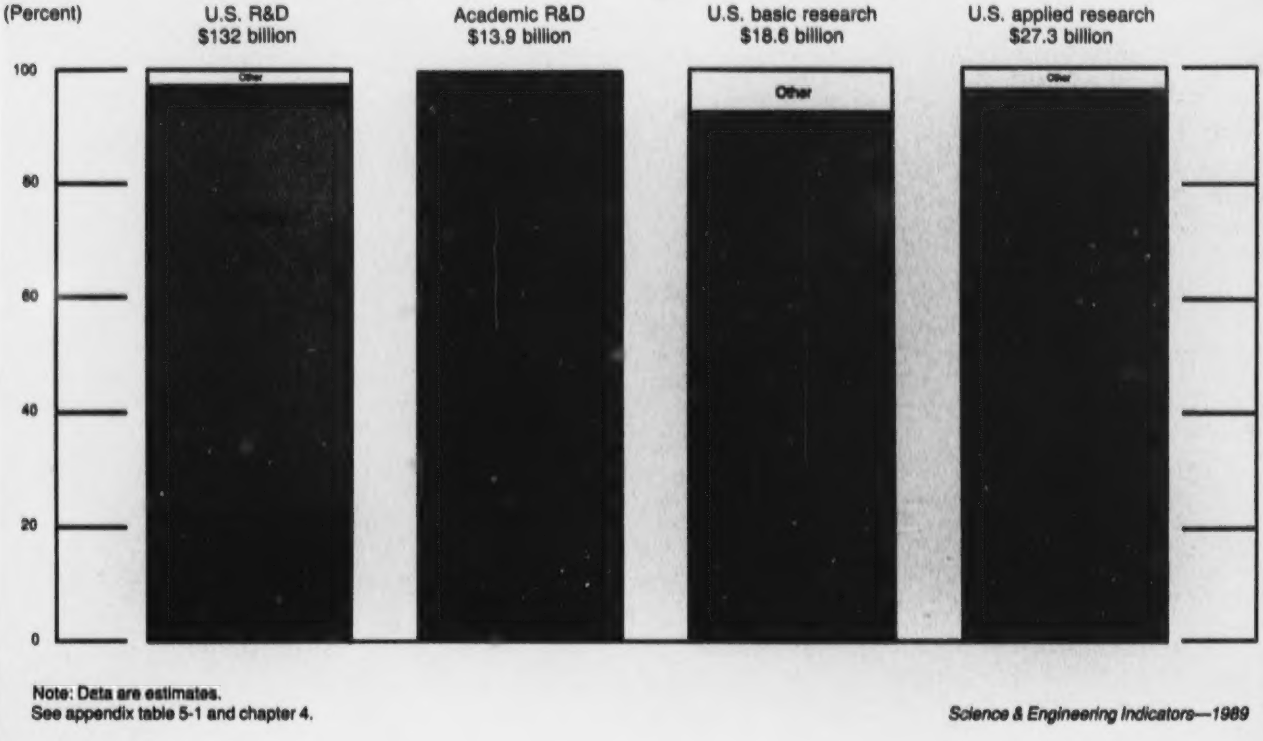
[5] NSF (1989b).

[6] Academic R&D is essentially funded via grants, contracts, and cooperative agreements. Funding usually includes expenditures for nonfixed equipment.

[7] Institutional funds are those an institution spends on R&D, including unreimbursed indirect costs associated with R&D projects financed by outside organizations and mandatory cost sharing on Federal and other grants. Sources of these funds are (1) general-purpose state or local government appropriations; (2) general-purpose grants from industry, foundations, or other outside sources; (3) tuition and fees; and (4) endowment income. See NSF (1989c).

Figure 5-1.
Academic and national R&D expenditures by character of work and performer: 1989



Note: Data are estimates.
See appendix table 5-1 and chapter 4.

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Federal Support for Academic R&D

Federal Support for Academic S/E Activities. Before discussing Federal patterns of academic R&D funding, it is useful to understand where academic R&D fits in the overall scheme of Federal support for academic S/E activities.[8] Federal funds provide support for the following academic S/E programs:

- R&D plant (facilities and equipment);[9]
- Facilities and equipment for instruction;
- Graduate student fellowships, traineeships, and training grants;
- General support for S/E research and education, without precise specification; and
- Other S/E activities, such as technical conferences, undergraduate activities, and teacher institutes.

Approximately 15 Federal agencies provided over 95 percent of S/E funds obligated to academic institutions for these various purposes in 1987.

In 1987, about 85 percent of Federal obligations for academic S/E were for R&D, in contrast to 66 percent in 1971. (See appendix table 5-4.) Fellowships, R&D plant, and general S/E activities each accounted for about 3 percent of total Federal academic S/E obligations in 1987; "other" activities accounted for about 6 percent. (See figure 5-2.)

Changes over time in the amounts of Federal support for various types of S/E programs may reflect shifts in policy and priorities. R&D was the only area of academic S/E where Federal funding increased (in constant 1982 dollars) during the 1970s.[10] However, support programs for women and minorities continued during the 1970s, and various types of support were devoted to such rapidly developing disciplines as computer science, materials research, and biotechnology. In contrast, a period of strong Federal support for graduate training ended around 1970. Between 1971 and 1980, Federal support for graduate research fellowships and traineeships declined by 75 percent, and, unlike support for other Federal S/E programs, did not recover during the 1980s.[11]

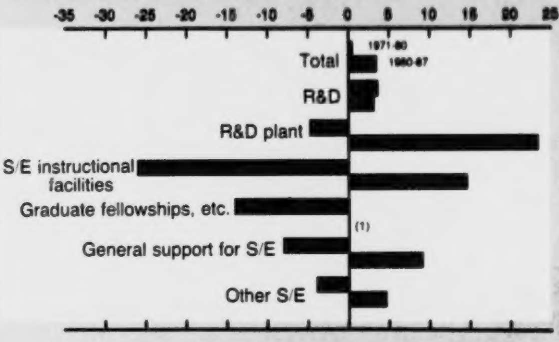
The Reagan Administration formulated a positive policy towards academic S/E support in 1983, as reflected in the subsequent S/E funding pattern. Large recent increases in Federal funding for facilities (over 100-percent increase in 1987 compared with 1986) partially reflect special line-item budgetary appropriations inserted by Congress for specific academic institutions.[12]

Support of Academic R&D by Federal Agencies. Federal obligations for academic R&D are increasingly concentrated in three agencies: the National Institutes of Health (NIH), NSF, and the Department of Defense (DOD). Together, these agencies provided an estimated 80 percent of total Federal financing of academic R&D in 1989, up from 66 percent in 1969. (See appendix table 5-5.) NIH, NSF, and DOD, as well as the National Aeronautics and Space Administration (NASA), are each estimated to have experienced between 3-percent and 5-percent average annual growth (constant 1982 dollars) in their funding of academic R&D during the 1980s. NIH was estimated to have provided almost 50 percent of all Federal support for academic R&D in 1989; the NSF share was estimated at 17 percent. DOD, after increasing its share of Federal support from 9 percent in 1977 to 16 percent in 1986, declined to an estimated 14-percent share in 1989.

University-Administered Federally Funded Research and Development Centers. During World War II and in the postwar period, several Federal agencies with

Figure 5-2.
Changes in Federal support for academic science and engineering, by type of activity

(Average annual percentage change in constant 1982 dollars)



Federal academic S/E obligations: 1987

	Millions of current dollars
Total	8,565
R&D	7,240
R&D plant	230
S/E instructional facilities	14
Fellowships, etc.	291
General S/E support	237
Other S/E	553

[1] Value is 0.1.
See appendix table 5-4.

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[8] Data on types of Federal funding for S/E activities come from a survey of the 15 Federal agencies most heavily involved in S/E support to academic institutions. See NSF (1988c) for the methodology used in the survey. Findings regarding Federal funding for other R&D-performing institutions, such as private foundations, exhibitors, and trade associations, also can be found in NSF (1988c).

[9] Federal support of S/E facilities and equipment for R&D and instruction are discussed under "Academic R&D Facilities and Instrumentation"; see pp. 111-13.

[10] For a detailed history of R&D during the Reagan Administration, see Teich and Gramp (1988).

[11] A concomitant rise in graduate research assistantships, included in these data under "R&D," has partly filled this gap. See chapter 2.

[12] See Cordes (1989).

specialized missions established R&D organizations called federally funded R&D centers (FFRDC), which they continue to support today.[13] In 1989, universities administered 18 of the 36 FFRDCs; these 18 FFRDCs received an estimated $3.6 billion in 1989 Federal obligations for R&D. This transfer of $3.6 billion from Federal agencies to university-affiliated FFRDCs for R&D represents a unique—if indirect—form of Federal support to science and engineering at U.S. universities. Researchers at university-affiliated FFRDCs often include faculty, academic nonfaculty, and graduate students, thereby providing opportunities for extensive interactions between researchers at FFRDCs and at universities.

Distribution of R&D Funds Among Specific Academic Institutions

Most academic R&D is concentrated in relatively few institutions. Of 3,400 higher education institutions in the U.S.,[14] the top 20 of them spent 35 percent of total academic R&D funds in 1987, and the top 100 institutions spent 83 percent of the total funds. (See text table 5-1 and appendix table 5-6.)

Industrial Support of R&D at Specific Academic Institutions[15]

Industry now supports over 6 percent of total academic R&D. While most of the industrial funds go to large, recognized research institutions, about a dozen academic institutions with relatively small R&D expenditures get more than 20 percent of their R&D funding from industry. These funding patterns partly reflect relationships that have developed between individual firms and schools.

In 1987, industry provided almost $800 million for academic R&D. Of the top 200 institutions ranked by their total academic R&D expenditures in 1987, the top 25 schools together received $260 million from industry, or 30 percent of the total support contributed by industry. The bottom 25 schools received $19 million, or 2.4 percent of total industry funds. The top 25 schools averaged $10.4 million each in industrial support; the lowest 25 schools averaged $0.8 million each. (See text table 5-2 and appendix tables 5-6 and 5-7.)

This distribution of industry funds follows an expected pattern. A more surprising finding is that industry was responsible for an average of 11.5 percent of the total R&D expenditures for the schools in ranks 176-200 in 1987, compared with a 5.5-percent share of the total R&D funds for the top 25 schools. Among the lower ranked academic institutions receiving relatively larger proportions of their R&D from industry, specialized smaller institutions tend to appear more often. These are often institutions with one R&D specialty that is closely linked with local industry.

Between 1980 and 1987, the number of schools receiving over 10 percent of their academic R&D support from industry increased from 24 to 49.[16] This increase may in part result from more institutions having separately reported industrial support data in 1987 than in 1980. (See text table 5-2.)

The increasing industry support for academic R&D may reflect increasing amounts of cooperative research activity between the two sectors. This conclusion is consistent with findings of increased industry-university coauthorship of research papers, discussed later in this chapter.

Academic R&D Expenditures by Field and Funding Source

The distribution of Federal and non-Federal funding of academic R&D in 1987 varied by field and subfield. (See appendix table 5-8.) For example, the Federal Government supported 66 percent of academic R&D expenditures in the medical sciences, but only 26 percent of academic R&D in the agricultural sciences; this latter figure reflects the traditionally strong role of states in supporting the agricultural sector.[17]

The majority of academic R&D expenditures in 1987 went to the life sciences, which accounted for 54 percent of total academic R&D expenditures, 52 percent of Federal academic R&D expenditures, and 56 percent of non-Federal academic R&D expenditures. (See appendix table 5-9.) The next largest block of academic R&D expenditures was for engineering, which had a 16-percent share in 1987.

Between 1977 and 1987, academic R&D expenditures for all fields combined grew at an average annual rate of

Text table 5-1. Distribution of R&D funds among academic institutions: 1987

Rank	Millions of dollars	Percentage of total
All institutions	12,082	100
Top 10	2,560	21
Top 20	4,233	35
Top 50	7,293	60
Top 100	9,981	83

See appendix table 5-6.

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[13] See chapter 4.

[14] The Carnegie Corporation classified 3,400 degree-granting institutions as higher education institutions in 1987. They include 4-year colleges and universities, specialized schools such as medical and law schools, 2-year community and junior colleges, and a few specialized institutions. Not included are more than 7,000 other postsecondary institutions (secretarial schools, auto repair schools, etc.).

[15] The corporate contributions to R&D may be understated in these data, since schools do not uniformly record and report corporate contributions.

[16] See NSB (1982), pp. 8-9.

[17] Of the $4.8 billion in non-Federal support for academic R&D in 1987, 18 percent went for agricultural sciences. The only subfield receiving a larger share of the non-Federal support for academic R&D was the medical sciences, with 21 percent. Only 4 percent of total Federal academic R&D funding was for agricultural sciences. (See discussion of state support for R&D in chapter 4.)

Text table 5-2. Industrial funding of academic R&D, by level of R&D expenditures: 1980 and 1987

Rank of academic institutions by total R&D expenditures[2]	Number of academic institutions with ≥10% of their total R&D derived from industry[1]		Average percent of total R&D funding derived from industry[1]	
	1980	1987	1980	1987
	Number		Percent	
1-200	24	49	4.6	6.7
1-25	2	2	4.4	5.5
26-50	2	5	4.4	6.7
51-75	2	3	3.8	5.6
76-100	1	7	4.6	7.3
101-125	3	8	5.5	9.4
126-150	4	6	5.9	7.6
151-175	2	7	5.6	9.9
176-200	8	11	11.4	11.5

[1] Omits data from institutions not separately reporting industrial R&D funding and from institutions reporting no industrial support. Omitted 32 institutions in 1980 and 11 in 1987.

[2] Ranking is derived by sorting institutions into groups of 25, from highest R&D expenditures to lowest.

See appendix table 5-7.

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5.4 percent in constant 1982 dollars. From 1986 to 1987, the rate increased to 7.1 percent. (See figure O-21 in Overview and appendix table 5-9.) Funding for computer science grew fastest during the decade, increasing at an average annual rate of 14 percent in constant dollars. R&D expenditures for computer science in 1987 were about 3 percent of total academic R&D. Engineering grew second fastest during the decade, at an average annual rate of 8 percent; for 1986 to 1987, the rate increased to 11 percent. Mathematical sciences, with 1.5 percent of 1987 academic R&D expenditures, grew third fastest, at an average annual rate of 7 percent between 1977 and 1987.

At the other end of the growth scale, the social sciences have barely increased in academic R&D expenditures since 1977, averaging annual increases of 0.5 percent in constant 1982 dollars and accounting for 4 percent of 1987 academic R&D funding.

Academic R&D Facilities and Instrumentation[18]

The country's research universities have experienced large increases in investment in academic R&D facilities and instrumentation during the 1980s.[19] Recent surveys indicate that, after an extended period of decreased support, steps are now being taken to meet needs in these areas.

While the terms "facilities" and "equipment" are defined specifically for each survey, in general, *facilities* come out of capital funds, are fixed items such as buildings, often cost millions of dollars, and are not included within R&D expenditures. *Equipment* and *instruments,* on the other hand, usually are movable, purchased with current funds, and included within R&D expenditures. Because the categories are not mutually exclusive, some large instrumentation systems could be classified as either facilities or equipment.

Facilities. In addition to the $12.1 billion that academic institutions spent for separately budgeted R&D activities in 1987, $1.8 billion was disbursed for capital investment in S/E facilities and fixed equipment to be used for R&D and instruction. In constant dollars, this represented an increase of 14 percent over 1986; the 1986 figure had in turn been an increase of 18 percent over 1985.

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[18] Data on facilities and instrumentation are taken primarily from the following three sources:

- *Academic Science/Engineering: R&D Funds, Fiscal Year 1987.* The term facilities as used in this survey stands for capital investment expenditures for S/E research or instruction at those universities and colleges spending $50,000 or more annually on separately budgeted R&D. See NSF (1989c).
- *Scientific and Engineering Research Facilities at Universities and Colleges: 1988.* Facilities are physical plant, including infrastructure (power), fixed equipment (benches, fume hoods), and nonfixed equipment costing more than $1 million. The survey also includes information on R&D space. See NSF (1988a), p. D-4 for definitions.
- *Academic Research Equipment in Selected Science/Engineering Fields: 1982-83 to 1985-86.* Equipment with an original purchase price of $10,000 to $1 million was included in this survey of academic departments covering the major S/E disciplines. See NSF (1988b), p. A-11 for definitions.

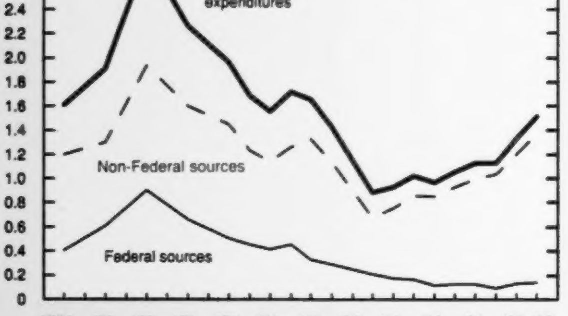
[19] The terms "instrumentation" and "equipment" are used interchangeably.

Total capital expenditures for academic S/E facilities (plant and fixed equipment) increased during the 1980s at an average annual rate of 7 percent in constant 1982 dollars. As noted above, recent increases have been even greater. (See figure 5-3 and appendix table 5-10.) Among the S/E fields, engineering has enjoyed the highest rate of growth—an average of 18 percent per year in constant 1982 dollars since 1980. Mathematical/computer sciences were second with 9-percent average annual growth between 1980 and 1987. (See appendix table 5-11.) By contrast, average annual increases between 1980 and 1987 were 0.3 percent for the environmental sciences and 2 percent for social sciences.

Non-Federal sources provide most of the funds for capital expenditures. Their proportion has been increasing—71 percent in 1970, 81 percent in 1980, 92 percent in 1987. Non-Federal sources, which include state and local governments, special bonds, donations, and other sources, grew an average of 9 percent per year in constant 1982 dollars between 1980 and 1987. Between 1985 and 1987, Federal spending for academic R&D facilities increased more than 50 percent in constant dollars, while non-Federal sources increased 33 percent.

Construction costs of academic S/E research facilities are expected to reach \$3.4 billion in current dollars in 1988+1989, up from \$2.1 billion in 1986+1987.[20] Between 1986 and 1989, these construction projects were expected to increase existing research space by 22 million square feet, an increase of 19 percent over space available in 1985.

Figure 5-3.
Federal and non-Federal capital fund expenditures for academic S/E: 1964-87



[1]GNP implicit price deflators were used to convert dollars to constant 1982 dollars.

See appendix table 5-10. *Science & Engineering Indicators—1989*

New construction projects are increasingly expensive: in 1986+1987, for example, the cost of new academic R&D space in current dollars was \$206 per square foot, compared to \$287 per square foot in 1988+1989. (See appendix table 5-12.) Factors contributing to the markedly increased costs of facilities construction include the need for better data handling capabilities as well as more stringent standards for animal facilities, toxic waste disposal, and biohazard control.

Despite the increased funding, there is a large estimated construction backlog as well as a backlog of academic research facilities that need renovation and repair.[21] Institutions are deferring an estimated \$2.50 for every \$1.00 of construction that was planned through 1989. They are also deferring about \$3.60 in needed renovation and repair for every \$1.00 spent.[22]

Instrumentation. Throughout the 1980s, U.S. academic institutions have invested heavily in R&D instruments. Results of a survey of academic research equipment in selected fields showed that approximately 40 percent of all instrument systems in research use in 1985/86 had been acquired in the previous 3 years, and about 25 percent of instrument systems in use in 1982/83 had been retired from research by 1985/86.[23] The median age of the national stock of instruments (both in-use and not in-use) in 1982/83 and 1985/86 was 5 years. However, the median age of state-of-the-art instruments was 2 years, indicating the rapid pace of technological change in research instrumentation.

In general, current fund expenditures[24] for academic research instrumentation have grown in the 1980s, except during the 1981-83 recession.[25] (See appendix table 5-13.) Annual growth during the 1980s averaged 8 percent for Federal support and 10 percent for non-Federal support in constant 1982 dollars. Federal support accounted for about two-thirds of total current fund expenditures for academic research equipment during the 1980s; this percentage varied widely among individual fields, however.

Funds for instruments for computer science and mathematical sciences grew fastest, each increasing in constant 1982 dollars by a factor of about four since 1980. Equipment funds for all other S/E fields combined increased by less than a factor of two. Funds from non-Federal sources for social sciences instrumentation increased an average of 3.5 percent annually between 1980 and 1987, but this increase did not fully offset an average annual 6-percent decrease in Federal funding. Taking all fields together, current fund expenditures for purchasing instruments grew more slowly between 1986 and 1987 than between 1983 and 1986.

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[20] Data are aggregated into 2-year units because the data are more stable and some data were only available aggregated for 1988 and 1989. See NSF (1988b). See also a parallel report on biomedical research facilities, NIH (1989).

[21] Association of Physical Plant Administrators (1989); NSF (1989d); and NSF (1988a).

[22] In response to this long-term problem, Congress passed the Academic Research Facilities Modernization Act of 1988 authorizing NSF to set up a competitive grant program for the repair, renovation, and, in exceptional cases, replacement of academic research facilities. NSF (1989d).

[23] Data for the physical sciences, computer science, and engineering were collected for 1982 and 1985; data for the agricultural, biological, and environmental sciences were collected for 1983 and 1986. Therefore, data from this survey refer to 1982/83 data and 1985/86 data. See NSF (1988b). Unless otherwise noted, data are for instruments costing from \$10,000 to \$1 million.

[24] Current funds—as opposed to capital funds—are those in the yearly operating budget for ongoing activities. Generally, academic institutions keep separate accounts for current and capital funds.

[25] Data used here are limited to funds for research instrumentation and do not include funds for instructional equipment.

A special survey of academic departments to obtain information on instruments in selected fields shows increases in expenditures and in numbers of instruments. Between 1982/83 and 1985/86, the number of *in-use* academic R&D instrument systems costing between $10,000 and $1 million increased almost 50 percent—from 36,300 to 53,900—in the fields surveyed.[26] (See appendix table 5-14.)

The average price (corrected for inflation) of in-use instrument systems remained at about $36,000 between 1982/83 and 1985/86. The aggregate purchase price for these instruments increased from $1.3 billion in 1982/83 to $1.9 billion in 1985/86, corrected for inflation.[27] The most notable change was a 22-percent decrease in the average price of the in-use stock of instruments in computer science, dropping from $58,000 to $45,000.

Costs of purchasing and repairing instruments, corrected for inflation, increased between 1982/83 and 1985/86. (See appendix table 5-15.) Expenditures for purchasing new or used equipment increased by 48 percent, with such purchases accounting for 75 percent of total instrument costs in 1985/86. Maintenance and repair costs increased 26 percent, and accounted for 16 percent of departmental instrument-related expenditures in 1985/86. In contrast, expenditures for research-related computer services declined substantially during the 3-year interval.

Supercomputer Installations. Supercomputer installations are an indicator of a country's ability to do certain types of advanced research. The U.S. leads the world in numbers of supercomputer installations with 272 at the end of 1988. U.S. universities have about 20 percent of these U.S. supercomputers, with the remaining 80 percent divided evenly between industry and government. (See text table 5-3.) U.S. supercomputing capability has grown rapidly, increasing by 69 percent between 1986 and 1987, and by 33 percent between 1987 and 1988.

With 172 installations, Japan is second among world countries in number of supercomputer installations. In contrast to the distribution in the U.S., the Japanese industrial sector accounts for almost three-quarters of the country's supercomputer installations. U.S. manufacturers provided about 40 percent of the supercomputer facilities available in Japan in 1988; Japanese manufacturers provided the remaining 60 percent.[28]

Library Costs for Serials[29]

Like facilities and instrumentation, libraries are crucial to maintaining academic R&D capability. The rapidly in-

Text table 5-3. Cumulative number of general-purpose supercomputer installations in Japan and the U.S.: 1983-88

	Japan				United States[1]			
	Total	Universities	Government	Industry	Total	Universities	Government	Industry
1983	5	2	0	3	46	3	23	20
1984	13	3	3	7	53	5	26	22
1985	27	6	6	15	89	14	39	36
1986	58	14	9	35	121	14	57	50
1987	121	24	13	84	204	36	79	89
1988	172	33	15	124	272	57	107	108

[1] Data are for U.S. vendors only; they have provided almost all supercomputers used in the U.S.

Note: These data are somewhat uncertain because definitions of supercomputers change and because some installations counted here are no longer in use.

SOURCES: United States: NSF, Division of Advanced Scientific Computing; Japan: Tokyo Office of the U.S. NSF, Report Memorandum #184, August 10, 1989.

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[26] The *total* national stock of instruments includes instrument systems purchased but not yet in use, in-use instruments, and inactive or inoperable but not discarded systems. Total national stock increased from 46,500 instruments to 62,200 instrument systems between 1982/83 and 1985/86. Of the 62,200 instrument systems, 2 percent were purchased but not yet in use, and 15 percent were inactive or inoperable. See NSF (1988b) for further breakdowns of these data.

[27] The aggregate purchase price for all systems (in-use and not in-use) costing between $10,000 and $1 million was $1.6 billion in 1982/83 and $2.2 billion in 1985/86, corrected for inflation. In addition, there was another $0.7 billion in 1982/83 and $1.1 billion in 1985/86 worth of large instrument systems, generally over $1 million each; most of these systems were for general-purpose research computer centers and high-energy physics systems. These large systems are not discussed here or included in totals.

[28] As of 1988, based on cumulative data, U.S.-manufactured supercomputers were distributed around the world as follows: U.S., 52 percent; Japan, 14 percent; other countries, 34 percent.

[29] The terms "serials" and "periodicals" are used interchangeably. The term chosen is the one used by the source of the information being discussed.

creasing costs of serials—especially in the areas of science, technology, and medicine—have put financial pressure on research libraries and generated concern throughout the scientific community.[30]

Costs Highest for Science Serials. Periodicals in the sciences, technology, and medicine tend to be more expensive than serials in most other fields. (See appendix table 5-16.) For example, the average 1989 subscription price was $308 for the 10 library categories of science, compared with $140 for the 10 categories of social science.[31] These prices were based on a data base of approximately 55,000 domestic and foreign titles. A different data base, consisting of a fixed set of 3,900 domestic periodicals, shows that science-related periodicals have increased in price during the 1980s more rapidly than periodicals in other fields.[32]

Costs of Foreign Periodicals Also Rise. Prices of serials published in foreign countries have increased rapidly, partly because of the weakening dollar compared to foreign currencies. This increase, however, may have temporarily slowed. The average 1-year subscription rate for foreign titles (all fields) increased 3 percent between 1988 and 1989, compared with 17 percent and 19 percent for the two previous annual intervals.[33] In 1989, average subscription prices (all fields) of U.S. and foreign serials were similar: $148 for domestic titles and $143 for foreign titles.

High Costs Require Hard Choices. As a major source of information about university research libraries, the Association of Research Libraries (ARL) has issued a report that relates the pricing policies of several major scientific publishers to increases in serials prices.[34] Between 1986 and 1988, expenditures for total serials at the ARL member libraries (107 university research libraries and 12 independent research libraries) increased 30 percent, but the number of current serials remained constant and numbers of monographs (books) purchased were cut by 15 percent. ARL does not have data to indicate whether prices of science-related serials were a major factor behind these findings.

Current serials have remained about 20 percent of expenditures at ARL libraries throughout the decade in the median university library.[35] However, overall library expenditures have been increasing faster than inflation during the decade. In the 1980s, library investment in automation and communication equipment has been a factor in these increasing costs.

DOCTORAL SCIENTISTS AND ENGINEERS ACTIVE IN RESEARCH

This section describes characteristics of doctoral scientists and engineers who work in academic institutions and whose primary or secondary work activity is R&D (basic research, applied research, or development).[36] Data about the overall doctoral basic research workforce are included to provide a perspective on academic basic researchers. The discussion is limited to doctoral researchers because they have major roles in academic R&D activities.

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[30] See Kingson (1989); Kalfus (1989); and Koshland (1989).

[31] Young (1989).

[32] Young and Carpenter (1989).

[33] Young (1989).

[34] See ARL (1989b). The report also observes that the increased size of many journals affects prices.

[35] See ARL (1989a).

[36] Data in this section come from the Survey of Doctorate Recipients conducted biennially by the National Research Council (NRC) for NSF. In this section, "academic institutions" refer to 4-year colleges, universities, and medical schools, as identified by the respondents. Federally funded research and development centers comprise all FFRDCs.

A recent broad assessment of the National Science Foundation's surveys of scientists and engineers (NRC, 1989) has noted limitations of this doctorate survey and has recommended improvements.

Examples of Library Expenditures for Science Serials

The price increases in science-related serials are of major concern to librarians and researchers because these serials are a significant portion of the serials and monograph acquisitions budgets of research libraries. However, because libraries usually have not classified their serials and monograph expenditures into science and nonscience categories, there are no national data on their relative expenditures for science-related and other periodicals.

Several studies are under way to address this data need. Results suggest that science-related serials constitute over 50 percent of the current serials budgets of typical research libraries.

- A study at the University of Nebraska at Lincoln showed that 67 percent of serials expenditures for 1988/89 were in the science, agriculture, technology, and medical categories, while these four categories accounted for a much lower 45 percent of the *number* of serials purchased. (Information provided by Kent Hendrickson, Dean of Libraries of the University of Nebraska, Lincoln; personal communications, August 1989.)

  (Dean Hendrickson also reported that expenditures for science-related serials constituted between 58 percent and 67 percent of serials expenditures at his libraries between 1980 and 1987. Cancelled subscriptions to current serials during that period totaled $250,000 out of an annual current serials budget of about $2 million.)

- Louisiana State University also spent more than half (55 percent) of its 1985/86 serials budget for science-related serials. (Information provided by Charles Hamaker, Louisiana State University; personal communication, August 1989.)

- In analyzing serials prices, nine Midwestern academic research libraries found that 72 percent of serials whose subscriptions cost $200 or more were in the science, agriculture, technology, and medical categories. Those four categories accounted for over 85 percent of the expenditures for the $200-plus subscriptions at these libraries.

Numbers of Academic Researchers in Various Fields

In 1987, there were 155,000 doctoral scientists and engineers whose primary or secondary work activity was academic R&D.[37] (See appendix table 5-17.) They represented 37 percent of employed S/E doctorates in the United States in 1987. Scientists made up 88 percent and engineers 12 percent of the total; these proportions were about the same as in 1977. (See figure 5-4.) Life scientists were the largest single group of doctoral scientists and engineers in academic R&D in 1987, constituting 34 percent of the total.

The numbers of doctoral scientists and engineers in academic R&D increased by 65 percent during the 1977-87 decade. Growth appeared to be especially rapid between 1985 and 1987.[38] (See figures 5-5 and 5-6 and appendix table 5-17.) Over the 1977-87 decade, the highest rate of increase occurred among computer scientists, whose numbers tripled from 1,200 to 3,500.

Women in Academic R&D. While women increased their percentages in all fields of academic R&D in recent years, some fields still have relatively few women. (See figure 5-7 and appendix table 5-18.) Overall, the percentage of women doctoral scientists and engineers in academic R&D increased from 10 percent in 1977 to 16 percent

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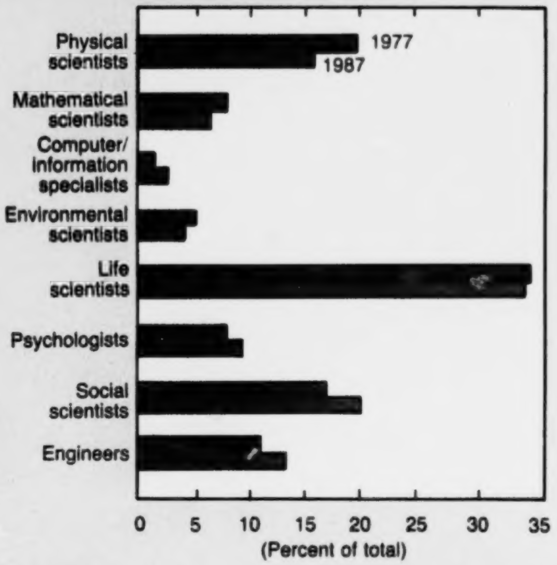
[37] The 1987 survey question on primary and secondary work activity reads: "From the activities listed below, select your primary and secondary work activities . . . in terms of time devoted during a typical week." Because many faculty members who devote substantial time to R&D often consider another activity (for example, teaching) to be their primary work activity, those survey respondents who selected academic R&D as their primary or secondary work activity are included here. Inclusion of both sets of respondents results in approximately twice as many as when only primary work activity respondents are counted, and ensures that all individuals involved in academic R&D are counted.

Data in some of the appendix tables differ from the comparable data in *Science & Engineering Indicators—1987* because the latter used a somewhat different set of respondents.

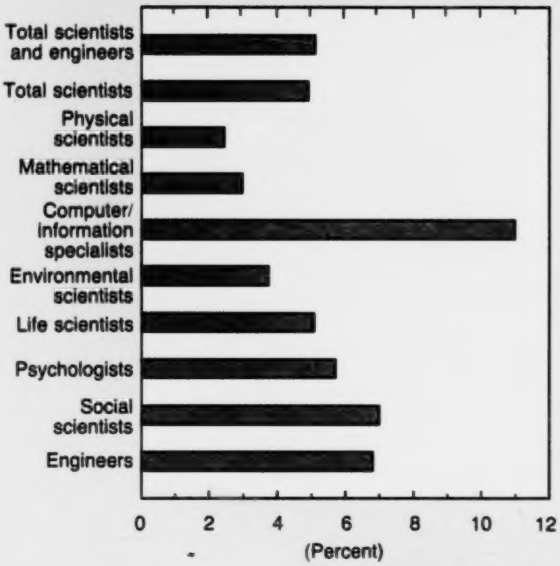
[38] The 1987 wording of the survey question about work activity involving basic research and applied research differed slightly from that in 1985. The 1987 survey defined basic research as "study directed toward gaining scientific knowledge primarily for its own sake." Applied research was "study directed toward gaining scientific knowledge in an effort to meet a recognized need." Earlier surveys had no clarifying definitions. Because of this difference, data from the 2 years may not be exactly comparable. However, a similar sharp increase between 1985 and 1987 was seen in numbers of academic R&D researchers when the responses were analyzed only by primary work activity. In the analysis by primary work activity, half of the increase was accounted for by decreases in the "other" and "teaching" categories; the remainder was accounted for by the increase in total doctorates employed in academic S/E, all of whom apparently went into R&D. A similar analysis was not available for primary and secondary work activities combined.

Figure 5-4.
Distribution of doctoral scientists and engineers in academic R&D, by field: 1977 and 1987



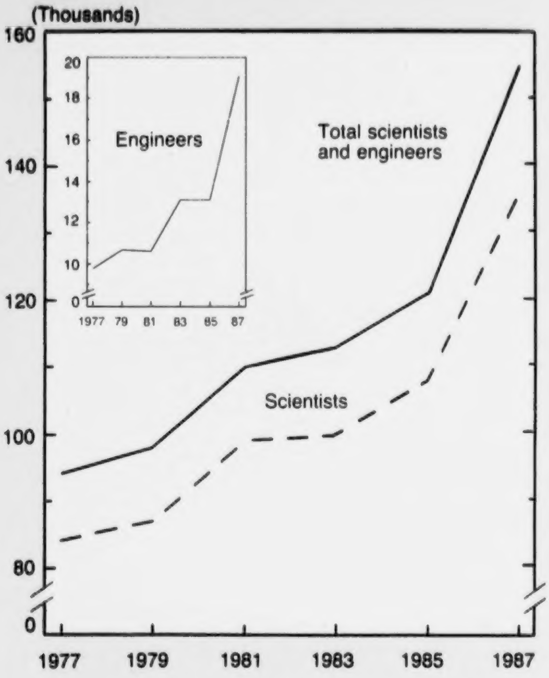
See appendix table 5-17. *Science & Engineering Indicators—1989*

Figure 5-5.
Average annual percentage growth rate of doctoral scientists and engineers in academic R&D, by field: 1977-87



See appendix table 5-17. *Science & Engineering Indicators—1989*

Figure 5-6.
Doctoral scientists and engineers in academic R&D: 1977-87



See appendix table 5-17.

Science & Engineering Indicators—1989

in 1987. In the fast-growing computer science field, the proportion of women increased from 5.3 percent in 1977 to 10 percent in 1987. Among the social sciences, which also grew rapidly during the decade, the proportion who were women increased from 12 percent in 1977 to 20 percent in 1987. The proportion of women doctorates in academic R&D in the various fields approximately reflects their representation in the doctoral S/E workforce in those fields.[39]

Minorities in Academic R&D. Whites still make up almost 90 percent of the academic R&D workforce, although racial minorities and Hispanics increased their representation during the 1977-87 decade.[40] Except for Asians, however, overall percentages of minorities in academic R&D remained below 2 percent in 1987. (See appendix table 5-18.) Blacks increased their overall percentage in academic R&D from 0.8 percent to 1.4 percent during the decade. In 1987, they were more heavily represented in the social sciences and the life sciences than in other fields.

Black women showed especially interesting gains. In 1987, 31 percent of black doctoral scientists in academic R&D were women.[41] This figure is substantially higher than the 18-percent figure for Asians and for whites. (See figure 5-7.) This higher representation of black women was also evident in 1977. The number of black women doctoral scientists increased from 131 to 611 over the 10-year period, an almost fivefold increase; the number of black men scientists doubled, reaching 1,381.

Hispanics accounted for 1.7 percent of S/E doctorates in academic R&D in 1987, compared with 1.0 percent in 1977. As with blacks, they are most heavily represented in the life sciences and social sciences. Hispanics' greatest percentage increase occurred in engineering, where their numbers rose from 69 in 1977 to 385 in 1987.

Asian representation in academic R&D rose to 9 percent in 1987. (See appendix table 5-18.) Among major fields, they were most heavily represented in engineering—18 percent in 1987. Among Asians, 14 percent were women, whose shares by field were generally similar to those for white women. (See figure 5-7.) The major exception was physical sciences: 13 percent of Asian physical scientists were women, in contrast to 7 percent of white physical scientists.

Academic and Nonacademic Doctoral S/E Basic Researchers

Employment by Sector. The total number of doctoral S/E basic researchers increased from 88,000 in 1977 to 133,000 in 1987, a 51-percent increase.[42] Nonacademic basic researchers increased 30 percent, from 21,900 to 28,600. With a 48-percent increase in basic researchers, nonprofit organizations showed the largest increase among nonacademic sectors. (See appendix table 5-19.)

Almost 80 percent of doctoral scientists and engineers in basic research in 1987 were also in academia. Thus, most of the broad demographic characteristics of the two groups are similar in terms of gender, race/ethnicity, and distribution by field. Moreover, academia employed almost all of the doctoral basic researchers in some fields—e.g., mathematics, 97 percent; sociology/anthropology, 97 percent; and economics, 93 percent.

Industry employed the next largest percentage of doctoral basic researchers—8.6 percent. (See figure 5-8 and appendix table 5-19.) Although it employed less than 10 percent overall of basic researchers, the industrial sector employed 19 percent of all engineers doing basic research and 25 percent of the computer scientists in basic research in 1987. Industry also more than doubled its number of life scientist doctorates in basic research between 1977 and 1987 (from 1,400 to 3,100). This increase probably reflects recent industrial emphasis on development of biotechnology products.

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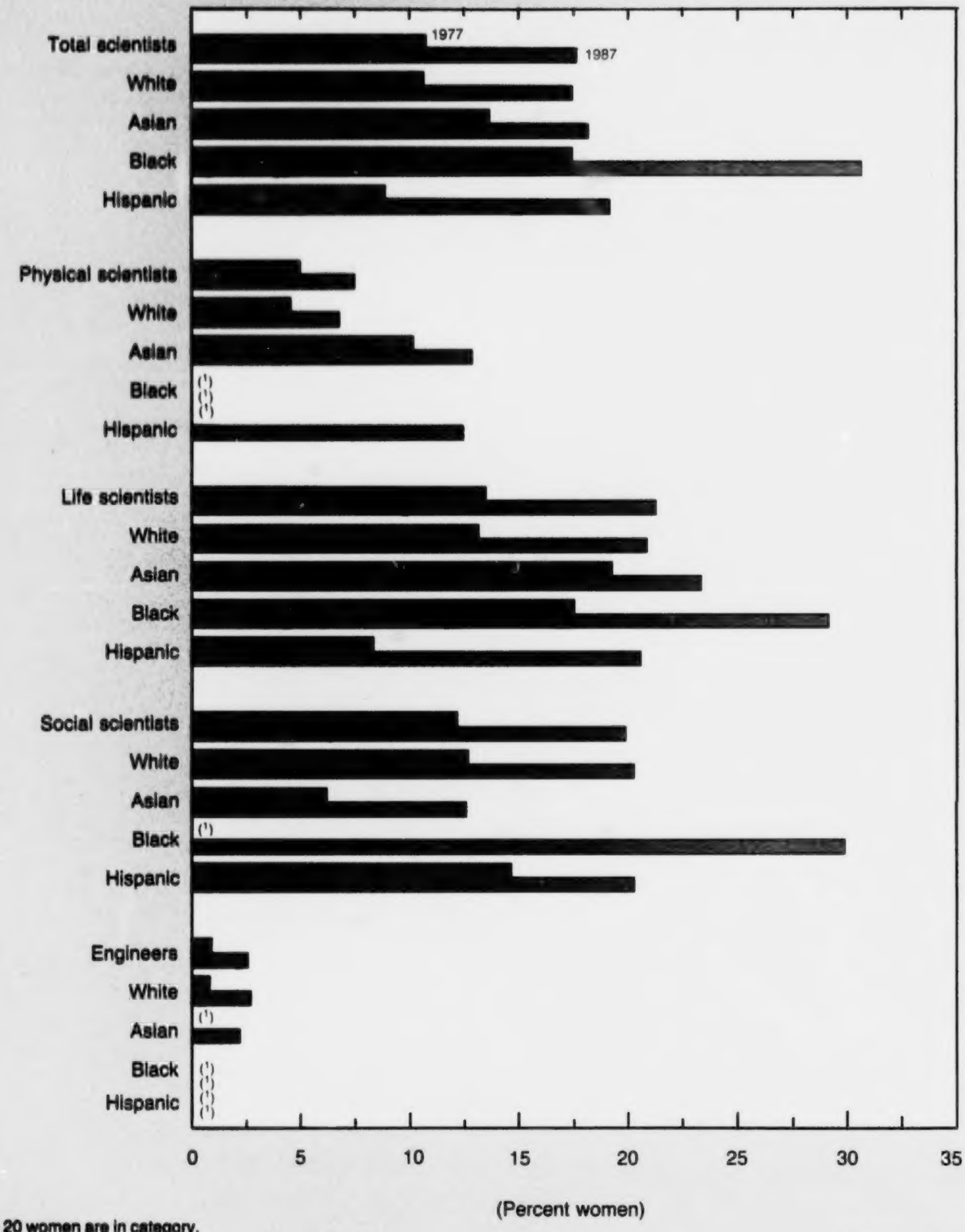
[39] See chapter 3 for the distribution of women doctorates by field in the total S/E workforce.

[40] Hispanics include members of various racial groups.

[41] Only doctoral *scientists,* rather than scientists and engineers, are discussed here, since there were fewer than 20 black women doctoral engineers in 1987.

[42] As with the academic R&D doctoral personnel data, these 1987 figures are not necessarily exactly comparable to data from earlier years because of changes in the 1987 survey question on character of work.

Figure 5-7.
Percentage of women doctoral scientists and engineers in academic R&D, by race/ethnicity and field: 1977 and 1987



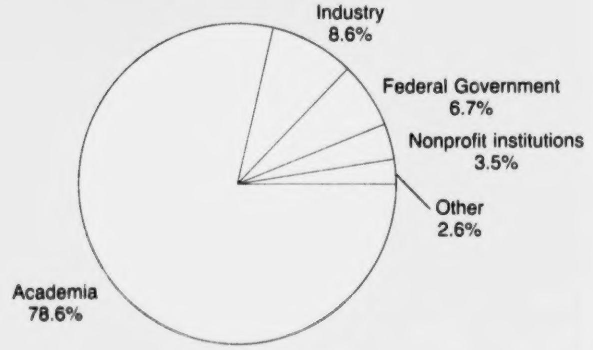
¹Fewer than 20 women are in category.
See appendix table 5-18.

Science & Engineering Indicators—1989

Minorities and Women in Basic Research. Among doctoral basic researchers in 1987, 1.1 percent were black; 25 percent of these were women. (See appendix table 5-20.) However, the absolute numbers of black basic researchers remained low (1,277 men and 416 women in 1987). Asians made up 6.8 percent of the doctorate S/E basic research workforce in 1987; 15 percent of the Asians were women. Asians are especially prevalent in engineering, where they accounted for 26 percent of basic researchers in 1987; the comparable figure in 1977 was 15 percent.

Employment sectors vary in their proportions of women and minorities doing basic research, but the overall numbers and proportions of women and minorities in the sectors increased between 1977 and 1987. For example,

Figure 5-8.
Employment of doctoral scientists and engineers in basic research, by sector: 1987



See appendix table 5-19. *Science & Engineering Indicators—1989*

over the decade, the proportion of doctoral basic researchers who are women increased:

- In academia, from 11 percent to 17 percent; and
- In the Federal Government, from 7.3 percent to 12 percent.

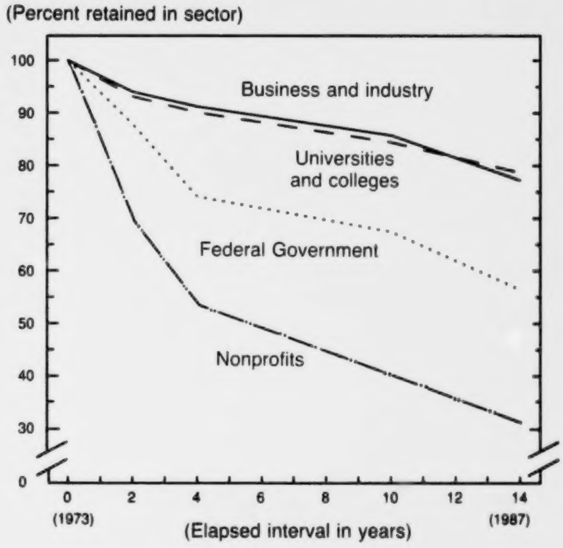
Also in the Federal Government, the percentage of black doctorates in S/E basic research increased from 1.2 percent to 2.1 percent, or from 85 to 188 individuals.

With Asians comprising 14 percent of its doctoral basic researchers, industry had a higher Asian representation than any other sector in 1987. Also, industry increased its percentage of basic researchers who are women from 5.5 percent in 1977 to 12 percent in 1987. As in academic R&D, women were especially prevalent in life sciences: 21 percent of industrial life sciences basic researchers were women in 1987, compared with 10 percent a decade earlier.

Retention of Doctoral S/E Researchers in Employment Sectors and Research Activities[43]

Retention in Employment Sectors.[44] The largest percentage of doctoral scientists and engineers in research who are going to leave their employing sector do so during their initial 2 years in that sector; longitudinal surveys show that decreasing percentages leave during subsequent time intervals. (See figure 5-9 and appendix table 5-21.) While 7 percent of male doctorates in academic R&D in 1973 had left that sector 2 years later, only 21 percent had left after 14 years.[45] In other words, 79 percent of those working in academic R&D in 1973 were still in academia 14 years later (although not necessarily in R&D). The retention rates for women follow similar patterns, although the rates are somewhat lower than for men.[46]

Figure 5-9.
Retention of doctoral scientists and engineers in employment sectors, by number of elapsed years



Note: Data are for men, although women show similar results.
See appendix table 5-21. *Science & Engineering Indicators—1989*

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[43] These data come from the NRC/NSF Survey of Doctorate Recipients data base. A weighted sample of new doctorates from each year enter the survey, and are surveyed in subsequent years. No new entrants are added to an earlier year's cohort. Thus, attrition occurs. The analysis here was based on respondents who answered the NRC/NSF Survey of Doctorate Recipients questionnaire in both years of the interval being analyzed. Because NRC used varied sampling strategies over the years, it is not very useful to compare actual numbers of respondents at the different times. However, there were 15,000 matched respondents for 1973 and 1975; 6,000 of them also matched for 1973 and 1987.

[44] For this and the following subsection only, the term "researcher" refers to doctoral researchers in nonacademic basic research or in academic R&D.

[45] Fourteen years was the longest time interval available in analysis of longitudinal survey data. The NRC/NSF Survey of Doctorate Recipients data base was used to follow movement among repeat responders. No corrections were made for nonresponders.

The estimates of retention have some uncertainty. Data from the 2-year initial time period probably overestimate retention rates, because the baseline sample contains people who have just started a job as well as those who have been at a position or with an employer for longer time periods. By contrast, doctorates in the 10- and 14-year samples have been in the same or related positions for at least as long as the time interval, and apparently are more stable in their positions. It is also possible that those who have not changed employers are more likely to receive subsequent questionnaires (because they have not changed addresses) than researchers who have moved, again leading to a possible overestimate of retention rates.

[46] Because of the much larger numbers of males compared with females in the doctoral S/E workforce, the totals are largely determined by the male pattern. Moreover, the retention rates vary the most in those categories that contain fewer individuals—for example, women in the nonprofit or industry sector during the 1970s.

Overall, the retention rates are generally similar when the same number of elapsed years (i.e., 2, 4, or 10 years) are compared for different calendar year intervals, for example, 1973-77 compared to 1983-87. Retention rates vary greatly among sectors, with the industrial and academic sectors showing rates very similar to each other, and both considerably higher than those of the Federal Government and nonprofit organizations. (See figure 5-9.) Relatively little movement of researchers occurs between the industrial and academic sectors, with 2-percent to 3-percent movement in either direction during selected 2-year intervals.[47] However, because there are many more researchers in the academic sector, this rate suggests that much larger numbers of academic researchers move to industry than vice versa.

Retention of Doctoral Scientists and Engineers in Research. Individuals were considered to have stayed in research from time$_1$ to time$_2$ if they were in academic R&D or nonacademic basic research when surveyed at both time$_1$ and time$_2$. Approximately 20 percent to 30 percent of researchers in a given year are no longer working at these research activities 2 years later. (See text table 5-4 and appendix table 5-22.) However, the rate at which scientists and engineers leave these activities decreases over longer time intervals. Thus, while 70 percent to 80 percent stay in research over 2-year periods, 60 percent of men and 55 percent of women were still doing nonacademic basic research or academic R&D when surveyed after 14 years (1973-87).

These findings suggest there is a large turnover of doctoral level basic researchers soon after they begin research. Recent Ph.D.s in postdoctoral positions may be unable to get another research position; faculty who do not get tenure may move to positions where academic R&D or nonacademic basic research is no longer their primary or secondary work activity; some scientists and engineers may find they do not want to continue in academic R&D or nonacademic basic research.

Text table 5-4. Retention of doctoral scientists and engineers in research for various time intervals since 1973

	Elapsed time	Retention in research	
		Male	Female
	—Years—	—Percent—	
1973-75	2	80	79
1973-77	4	65	61
1973-83	10	58	51
1973-87	14	60	55
1977-79	2	74	72
1977-87	10	66	63
1983-85	2	75	74
1983-87	4	78	75
1985-87	2	83	81

Note: Data are for doctoral scientists and engineers whose primary or secondary work activity was nonacademic basic research or academic R&D in the first year of a time interval, and who also responded to the Survey of Doctorate Recipients in the final year of an indicated time interval.

See appendix table 5-22.

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A larger proportion of doctoral scientists and engineers apparently stayed in research in the 1980s compared with the 1970s. (See text table 5-4 and appendix table 5-22.) For example, the retention rates between the 4-year interval from 1983 to 1987 were higher than the rates between 1973 and 1977. The same qualitative finding holds for 1977 to 1987 compared with the earlier period 1973 to 1983. These results contrast with those discussed earlier for movements between sectors, where retention rates were largely independent of calendar time.

OUTPUTS OF ACADEMIC R&D: SCIENTIFIC LITERATURE, PATENTS, AND PRODUCTS[48]

The primary output of university research is new knowledge, usually measured by various types of publication counts. As an indicator of the impact that a publication has on other research, academic researchers often use citation data. Based on publication counts, U.S. academic institutions continue to produce a substantial share of the world's new S/E knowledge—albeit with increased interactions with researchers from other sectors and countries.

Bibliometrics is the generic term to describe data about publications. This section uses bibliometric data to explore trends in U.S. and world publication and citation data.[49] For example, bibliometric data permit tracking of patterns of collaboration among countries, among U.S. employment sectors, and among individual researchers. Current data show that:

- The U.S. is maintaining its large share of world science and engineering literature;
- Coauthorship is rapidly increasing among individuals, countries, and sectors; and
- There have been some specific changes over the past decade in intercountry citation patterns, although the overall patterns have remained unchanged.

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[47] NSB (1987), p. 94.

[48] In this section, academic institutions are essentially *all* U.S. educational institutions, including high schools. The terms "universities" and "academic institutions" are used interchangeably in this section. In this section, federally funded research and development centers comprise all FFRDCs, including those administered by colleges and universities.

[49] The publication data discussed here are taken from science literature indicators developed by Computer Horizons, Inc. (CHI), for the National Science Foundation. The CHI tabulations are derived from the Science Citation Index data base created by the Institute for Scientific Information. CHI has developed several major data bases. One covers the articles, notes, and reviews in a fixed journal set covering approximately 2,100 of the most significant S/E journals from 1973. A second data base covers articles, notes, and reviews in a fixed journal set of over 3,200 of the most influential journals from 1981 forward.

Throughout this section, the terms "papers," "articles," and "publications" are used interchangeably, and refer to the articles, notes, and reviews in the CHI bibliometric data bases.

University *patents* measure a different type of knowledge. A recent sharp increase in university patenting is an indicator of the expanding role played by academic R&D in technology development.

World S/E Literature: Comparisons and Interactions[50]

U.S. Share of World S/E Literature. Bibliometric data provide one way of looking at U.S. S/E activity in relation to that of other countries. In 1986, U.S. publications accounted for 36 percent of world publications in science and engineering, a figure that has been approximately constant since 1973 and very constant since 1981. (See appendix tables 5-23 and 5-24.) In all fields, the U.S. has a greater percentage of world publications than does any other country. The U.S. produces:

- 22 percent of the world literature in chemistry,
- 30 percent of physics publications, and
- Between 37 percent and 43 percent of the literature in the other major fields.

However, the U.S. world shares in mathematics, engineering/technology, and biology have dropped somewhat since 1973. (See text table O-1 in Overview and appendix table 5-23.) Interpretation of changes in other fields is uncertain because U.S. shares in all fields showed decreases when the number of journals analyzed was expanded by 50 percent in 1981.

Foreign Country Shares of World Literature. Among foreign countries, the United Kingdom, USSR, and Japan each contributed about 8 percent of world science and engineering literature in 1986, but the fields in which they contributed their largest shares differed. (See appendix table 5-25.) The United Kingdom made its greatest contributions in clinical medicine and biology (10 percent of world literature); the USSR provided 15 percent of world literature in both physics and chemistry; and Japan accounted for 13 percent of engineering/technology literature. One of the more notable changes in world shares is Japan's increase in world share of engineering/technology literature—from 9 percent in 1981 to 13 percent in 1986.[51]

Multi-Authored Papers. An ongoing increase in the average number of authors per paper suggests an increase in cooperation among scientists and engineers. Between 1973 and 1986, the average number of authors on world S/E publications increased from 2.3 to 3.0. (See appendix table 5-26.) Concurrently, the percentage of single-author papers decreased from 33 percent in 1973 to 19 percent in 1986. And, during the same time period, the overall percentage of S/E publications with four or more authors increased from 15 percent to 31 percent. (See figure 5-10.)

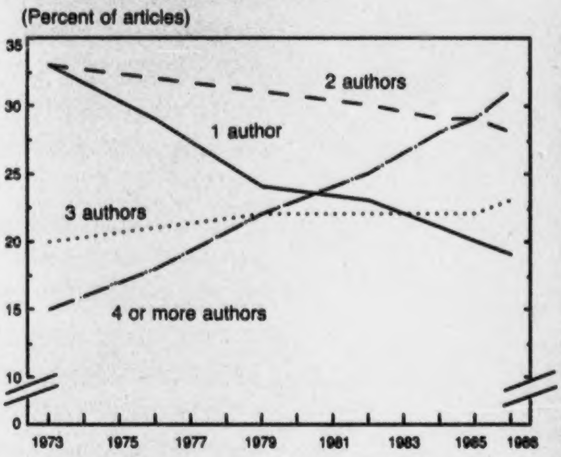
This trend toward more multi-authored papers may signal greater cooperation among individuals and groups, a move toward larger research groups, or increasing amounts of "big science." The trend might also reflect simply a tendency to give authorship to more contributors than in previous years.

The author distribution on mathematics papers contrasts strongly with that for other fields. Only 1 percent of mathematics publications in 1986 had four or more authors and 62 percent were single-author papers. These data suggest that mathematics research is a less collaborative activity than research in other fields.

International Coauthorship. Scientists and engineers throughout the world are increasingly coauthoring papers with researchers from other countries. In 1976, 4.0 percent of world science and engineering publications listed authors from more than one country; by 1986, this figure had increased to 7.5 percent. (See appendix table 5-27.)

S/E fields vary in degree of international copublication. At 13 percent, mathematics had the highest percentage of internationally coauthored articles in 1986—a somewhat surprising finding, given that the majority of mathematics papers have only one author. Earth/space sciences was

Figure 5-10.
Percentage of world S/E publications with 1, 2, 3, and 4 or more authors: 1973-86



See appendix table 5-26. *Science & Engineering Indicators—1989*

second with 12 percent of papers internationally coauthored, and physics was third with 10 percent.[52] International collaborations at large-scale facilities for physics and astronomy research may contribute to the international character of these research fields.[53]

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[50] These data are based on articles, notes, and reviews in journals from the 1973 and 1981 Science Citation Index Corporate Tapes. Articles written by researchers from more than one country are prorated across the *number of institutions involved from each country*, regardless of number of individual authors. For example, if an article has authors from two institutions in France and one institution from the U.S., it is counted as two-thirds of an article for France and one-third of an article for the United States. Articles attributed to U.S. sectors are similarly prorated. For some tabulations, articles are credited to a country, sector, etc., if at least one author is from the place of interest.

[51] For extensive bibliometric data for many of the world's countries, see Schubert, Glänzel, and Braun (1989). Their country publication shares are similar to those reported here.

There has been an overall increase in U.S. international coauthorship. In 1986, 10.2 percent of publications with at least one U.S. author were internationally coauthored, up from 5.6 percent in 1976. (See text table 5-5, figure O-17 in Overview, and appendix table 5-28.)[54] This rise was apparent among all U.S. employment sectors. (See appendix table 5-29.) Notwithstanding this steady increase, the U.S. percentage of internationally coauthored papers is still relatively low compared with that of various Western countries.

Japan and the USSR, like the United States, also show relatively low—but increasing—percentages of international coauthorship. (See figure O-17 in Overview and appendix table 5-28.) In 1986, 7.5 percent of articles with at least one Japanese author were internationally coauthored; over half of these were coauthored with the United States, and the next largest percentage with West Germany. In 1986, 3.3 percent of publications with at least one author from the USSR were internationally coauthored, primarily with East Germany and the rest of Eastern Europe. Only 0.4 percent of the USSR articles were written with U.S. researchers.

Text table 5-5. Internationally coauthored articles for selected countries: 1976 and 1986

	1976	1986
	— Percent[1] —	
West Germany	9.7	20.9
United Kingdom	10.0	16.6
Canada	12.4	19.4
France	10.3	21.3
USSR	2.0	3.3
United States	5.6	10.2
Japan	3.5	7.5

[1] Internationally coauthored articles are expressed as a percentage of all articles with at least one author from the country.

See figure O-17 in Overview and appendix table 5-28.

Science & Engineering Indicators—1989

U.S. Sector Interactions in S/E Publications

U.S. Authorship and Coauthorship by Sector.[55] The academic sector is responsible for over two-thirds of U.S. science and engineering publications. Of the 137,770 U.S. S/E publications in 1986, universities accounted for 70 percent. (See appendix table 5-30.) These proportions are about the same as they were in 1976.

By field, academic institutions in 1986 accounted for between 60 percent and 80 percent of publications in all fields except mathematics and engineering/technology. (See appendix table 5-30.) In mathematics, academic institutions were responsible for a far higher share—over 90 percent of publications in 1986. In engineering/technol-percent of publications in 1986. In engineering/technology, they were responsible for 55 percent of publications; this was a considerable increase over their 40-percent share in 1976. (Over the same period, the industry share of engineering/technology publications dropped from 39 percent to 26 percent.)

A trend of increasing cross-sector coauthorship suggests there is increased research cooperation among U.S. employment sectors. (See appendix table 5-31.) For example, between 1973 and 1986, industry showed a substantial increase—from 17 percent to 35 percent—in the proportion of papers it coauthored with other sectors. The various nonacademic sectors publish more frequently with the academic sector than with each other. The proportions of papers coauthored with universities has risen reasonably steadily since 1973. (See figure 5-11.) By 1986, academic researchers were coauthors on approximately 30 percent to 50 percent of papers from each of the other sectors.

University-Industry Coauthorship. Trends in university-industry coauthorship were analyzed to determine whether this indicator was consistent with other evidence of increased interaction between these two sectors. Overall, 28 percent of articles with at least one industry author were coauthored with a university author in 1986, compared with the 1976 figure of 15 percent. By field, the percentage of industry articles coauthored with university authors in 1986 ranged from a low of 18 percent in chemistry to approximately 40 percent in the three life sciences. (See figure O-26 in Overview and appendix table 5-32.)

From the academic sector's viewpoint, fewer than 4 percent of articles with one or more academic authors were coauthored with industry authors in 1986. (The percentage was even lower in 1976.) Universities coauthored more with nonprofits (7.4 percent) and government (9.6 percent) than with industry or FFRDCs in 1986.

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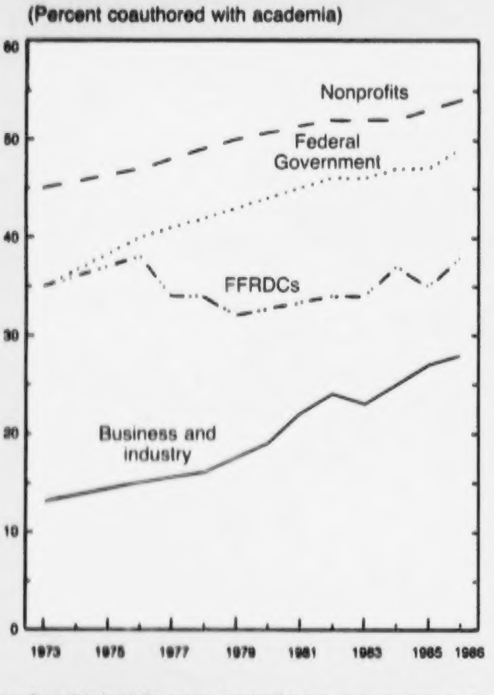
[52] Patterns of U.S. international coauthorship are similar to those worldwide. In 1986, U.S. researchers published most with foreign authors in mathematics (19 percent of U.S.-authored mathematics papers), earth/space sciences (16 percent), and physics (15.5 percent). (Data provided by CHI.)

[53] See Ailes, Coward, Owens, et al. (1988) for a discussion of large-scale research facilities in the U.S., Western Europe, and Japan. Examples are Fermilab in the U.S. and Centre Européen pour la Recherche Nucléaire (CERN) in Geneva for high-energy and particle physics; the Joint European Torus for atomic energy, and the European Molecular Biology Laboratory.

[54] Appendix tables 5-27 and 5-28 appear to show inconsistent degrees of international coauthorship. However, in appendix table 5-28, publications are counted at least twice, since they are counted for *each* author country. Appendix table 5-27 uses actual numbers of publications.

[55] See footnote 50.

Figure 5-11.
Proportion of U.S. S/E articles coauthored with U.S. academic institutions, by sector: 1973-86



Note: An article is attributed to a sector if one or more authors are from the sector.
See appendix table 5-31. *Science & Engineering Indicators—1989*

Citation Analysis in the Scientific Literature[56]

Authors cite each other's papers for many reasons, but analysts generally assume that rates of citation provide some measure of the quality, relevance, or interest—the impact—of the cited papers.[57] Analysts also use citation data to provide information on how various science and engineering fields and subfields may be related to each other.

U.S. References to Foreign Countries. Approximately 29 percent of references[58] in U.S. science and engineering papers are to foreign papers, a value that has persisted for the past decade. (See text table 5-6 and appendix table 5-33.) However, some notable changes for specific fields and countries have occurred. Over the 1977-86 period, U.S. publications decreased the percentage of their references to United Kingdom papers in all major fields. By contrast, U.S. authors increasingly cited papers from France, West Germany, and Japan. Although the share of Japanese references in U.S. papers increased more than a percentage point, Japanese papers still constitute a small share—3.5 percent—of total references in U.S. papers.

In general, citation patterns for individual fields follow those for all fields combined. Physics shows the greatest change; in 1977, foreign physics papers constituted 31 percent of physics references in U.S. papers, a percentage that had increased to 36 percent by 1986. Further analysis of this change shows that U.S. papers increased the number of citations to foreign physics papers faster than they increased the number of citations to U.S. physics papers.

Citation Patterns Between U.S. and Foreign Articles. In all fields combined, U.S. articles tend to cite U.S. publications almost twice as often as expected and to cite non-U.S. publications about half as often as expected, as estimated by relative citation ratios.[59] (See appendix table 5-34.) In other words, U.S. articles tend to *overcite* U.S. publications and to *undercite* non-U.S. publications. Foreign researchers cite U.S. papers in all fields combined exactly as frequently as predicted by the U.S. share of world literature: the relative citation ratio is 1.0. The relative citation ratios were surprisingly constant between 1977 and 1986, indicating little change in the relative amounts of attention that the citing authors devoted to the various cited categories.

The level of citation of U.S. papers suggests that U.S. researchers exert a substantial impact on foreign S/E publications. Since foreign papers for all fields combined cite U.S. papers as frequently as statistically expected, and the U.S. produces about 35 percent of the world S/E literature,

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[56] This analysis uses a methodology designed to minimize the spurious effects that occur because authors tend to cite their own country and sector much more when citing recent papers than when citing papers several years old. The cross-sector and cross-country citation analyses employed here were performed using a 2-year-lag, 3-year rolling cycle. This approach excludes cited papers from either the same year as the citing paper or from the immediate prior year, but uses citations from the previous 3 years. For example, if 1984 is the citing year, 1980-82 are the cited years. While this approach allows analysis of temporal trends, it is not useful for quickly detecting "hot" research areas.

[57] See Cozzens (1989), Lederman (1987), and OTA (1986) for discussions about what citation data mean. Cozzens divides citations into two broad categories: citations that bolster the findings and conclusions of the citing paper, and those whose purpose is to give credit to the work of previous researchers.

[58] The terms "citation" and "reference" are used interchangeably.

[59] Relative citation ratios (also called relative citation indexes) provide information on the relative impact of the cited papers. A relative citation ratio—for example, for the U.S. citing of French chemistry papers—is calculated as follows:

$$\frac{\dfrac{\text{Number of citations to French chemistry papers in U.S. citing publications}}{\text{Total number of chemistry citations in U.S. citing publications}}}{\dfrac{\text{Total number of published chemistry papers from France}}{\text{Total number of published chemistry papers in world}}}$$

If the ratio is greater than 1, the U.S. is citing French chemistry papers more than would be expected on statistical grounds. Essentially, the relative citation ratio measures the extent to which cited papers are getting more or less than their statistical share of attention as measured by citations.

Relative citation ratios can be subtly misinterpreted. For example, the smaller a country's share of world publications in a field, the larger its relative citation ratio can be, based purely on statistics.

Text table 5-6. Citations in U.S. papers to papers from selected countries: 1977 and 1986

Cited country	Year of citing papers	
	1977	1986
	— Percent —	
United States	71.5	70.5
All foreign countries	28.5	29.5
France	2.1	2.6
Japan	2.1	3.5
United Kingdom	7.3	5.9
West Germany	2.8	3.4

Note: Cited papers are counted in a 2-year-lag, 3-year rolling cycle. For example, citing papers published in 1986 provide data on cited papers published in 1982-84.

See appendix table 5-33.

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approximately 35 percent of citations in foreign S/E papers must be to U.S. publications.

U.S. Cross-Sector Citations. The various U.S. employment sectors overcite their own S/E literature in the same way that individual countries do;[60] they also usually undercite papers from other sectors, albeit to varying extents.[61] (See appendix table 5-35.) With few exceptions, this overall pattern was generally stable between 1977 and 1986.[62]

University papers dominate the references in U.S. publications. Because the academic sector produces 70 percent of the U.S. S/E literature, this finding is not surprising. In 1986, more than half the citations to U.S. papers were to the U.S. academic sector, except when industry was the citing sector. However, even industry has cited more academic papers than industry papers since 1984. (See appendix table 5-35.)

Citations in Engineering/Technology Papers. As an indicator of the role of basic research in the development of technology, citations in engineering/technology journals were examined. Engineering/technology papers primarily cite their own field. In 1984, 67 percent of their references were to other engineering/technology papers; 16 percent of the references were to physics papers, and 9 percent to chemistry papers. (See appendix table 5-36.) These proportions have remained constant since 1976.

Further analysis focused on the distribution between applied research and basic research of the cited physics and chemistry papers and on the comparison of this cited distribution of papers with the world distribution.[63] (See appendix table 5-36.) Of the 25 percent of citations in engineering/technology papers to chemistry and physics papers, about a third of the cited chemistry and physics papers are in basic research journals and two-thirds in applied research-targeted basic research journals. However, this citation distribution by type of research is the reverse of the world distribution of papers in these two fields. Thus, engineering/technology papers show some attention to basic research in chemistry and physics, but preferential attention to applied research-targeted basic research in those fields.

Patents Awarded to Universities

University patenting has increased during the 1980s,[64] due in part to the 1980 change in the U.S. patent law that allows universities and small businesses to retain title to inventions resulting from research funded by the Federal Government. U.S. universities received 2.0 percent of patents awarded to U.S. inventors in 1988, more than double their 0.9-percent share in 1978.[65]

Patent Classes. Universities concentrate their patenting in relatively few patent classes, many of which are in biomedical areas. Of the 404 patent classes of the U.S. Patent and Trademark Office, only 21 patent classes accounted for more than half of the 7,798 patents awarded to U.S. universities between 1971 and 1988. (See appendix table 5-37.) In 1988, universities patented most prolifically in four biomedical patent classes: these four classes represented 32 percent of university patents, compared with 5 percent of all patents awarded to U.S. inventors. (See text table 5-7.)

Characteristics of the Highest Patenting U.S. Universities. Nine of the ten U.S. universities with the largest numbers of patents in 1988 heavily patent in biomedical

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[60] Unpublished data from Computer Horizons, Inc., show that individual foreign countries overcite papers from their own country; this effect is most severe for papers published nearest to the publication year of the citing paper.

[61] Only papers with U.S. authors are counted as cited or citing papers in this section. Both cited and citing papers are counted as appropriate fractional papers when there are authors from more than one country or more than one sector. See footnote 50 for an explanation of assignment of fractional papers.

[62] Because of year-to-year variability in relative citation ratios, apparent time trends should be interpreted cautiously.

[63] The analysis used a four-level categorization system for S/E journals, developed by Computer Horizons, Inc. The categories ranged from the most applied technology to the most basic science.

The world distribution of papers by research category and field was provided by Computer Horizons, Inc., for 1973 to 1979. Because the proportions were constant during those years and consistent with later data, the 1973-79 distributions have been used.

[64] U.S. Patent and Trademark Office (1989).

[65] The minimum percentage of U.S.-invented university patents awarded to women was 1.8 percent in 1975, 2.5 percent in 1981, and 5.1 percent in 1987. In this last year, at least 36 women from U.S. universities were awarded patents. The percentage of *total* U.S.-invented patents awarded to women was at least 1.6 percent in 1975 and 2.9 percent in 1987.

The percentages for women are minimum figures since gender-ambiguous names could not be assigned. Because the number of unidentified and gender-ambiguous names exceeds the number of identified women, the percentage of women patent-holders could be considerably higher than the minimum figures presented here. CHI provided these unpublished data, based on the 100 top patenting universities in the United States, which account for over 90 percent of university patents. Gender was assigned based on names.

Text table 5-7. Most active patent classes for academic sector patenting: 1988

Patent class and name	Patents to academic institutions	Patents to U.S. inventors	Academic share of patents
	—— Number	——	—Percent—
Total, all classes	801	40,496	2.0
Total, these four classes	257	2,156	11.9
435 Chemistry: molecular biology and microbiology	91	441	20.6
514 Drug, bioaffecting and body treating compositions	80	823	9.7
128 Surgery	47	901	5.2
424 Drug, bioaffecting and body treating compositions	39	432	9.0

See appendix table 5-37 and chapter 6.

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areas, mirroring the pattern for all universities combined.[66] (See appendix table 5-38.) The sole exception, Caltech, gets small numbers of patents in a great variety of patent classes. These top 10 universities received 38 percent of the patents awarded to universities in 1986-88, a disproportionately large share. This distribution pattern also occurs with other indicators of university R&D; for example, these 10 universities receive a relatively large share of academic R&D funding. (See appendix table 5-6.) Furthermore, many of these top patenting universities also rank in the top 10 in numbers of publications in various fields.

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[66] Numbers of patents in 1988 for the year's top 10 patenting universities are: MIT, 63; University of California, 59; Stanford University, 54; University of Minnesota, 26; Johns Hopkins University and the University of Florida, 21 each; University of Wisconsin, 20; Caltech and the University of Texas, 18 each; and Harvard University, 17.

Dependence of Manufacturing Industries on Academic Research

Various efforts have been made to quantify the role that academic research plays in industrial development of new products. In the first empirical attempt to estimate the economic return to society from this research, Mansfield (forthcoming, 1990) found that industry depends heavily on recent academic research. (See text table 5-8.) A very rough estimate of the minimum annual social rate of return from the academic research discussed in this study was 28 percent.

Mansfield's results were based on a probability sample study of 76 major American firms in 7 manufacturing industries. Executives were asked about new products and processes they had introduced between 1975 and 1985. They said that a substantial proportion of these new products and processes depended on academic R&D, in that they either:

- Could not have been developed (without substantial delay) in the absence of recent academic research, or
- Were developed with very substantial aid from recent academic research.

The drug industry showed the greatest dependence on academic research, with 44 percent of its new products depending on such research.

Text table 5-8. Percentage of new products and processes based on recent academic research for seven U.S. industries: 1975-85

Industry	Percentage whose development depended on recent academic research[1]	
	Products	Processes
Information processing	28	27
Electrical	9	7
Chemical	8	6
Instruments	21	3
Drugs	44	37
Metals	22	21
Oil	2	2

[1] Percentage that either could not have been developed (without substantial delay) in the absence of recent academic research or that were developed with very substantial aid from recent academic research.

SOURCE: Mansfield (forthcoming, 1990).

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REFERENCES

Ailes, C.P., H.R. Coward, S.J. Owens, et al. 1988. *International Cooperation in Large Scale Research: Summary Data.* Draft report prepared by SRI International for the National Science Foundation, Division of Science Resources Studies.

Association of Physical Plant Administrators of Universities and Colleges. 1989. *The Decaying American Campus: A Ticking Time Bomb.* Joint report with the National Association of College and University Business Officers. Alexandria, VA.

Association of Research Libraries (ARL). 1989a. *ARL Statistics 1987-88.* Washington, DC: ARL.

———. 1989b. *Report of the ARL Serials Prices Project.* Washington, DC: ARL.

Cordes, C. 1989. "Colleges Received About $289 Million in Earmarked Funds." *The Chronicle of Higher Education* 35, no. 21 (1 February): 1, A21-22.

Cozzens, S.E. 1989. "What Do Citations Count? The Rhetoric-First Model." *Scientometrics* 15: 437-47.

Kalfus, K. 1989. "Scientists Balk at Soaring Journal Prices." *The Scientist* 3, no. 15 (24 July): 1, 16.

Kingson, J.A. 1989. "Where Information Is All, Pleas Arise for Less of It." *The New York Times*, 9 July: E9.

Koshland, D. 1989. "Combating High Journal Costs." *Science* 244: 1125.

Lederman, L.L. 1987. "Science and Technology Policies and Priorities: A Comparative Analysis." *Science* 237 (4 September): 1125-33.

Mansfield, E. Forthcoming, 1990. *The Social Rate of Return from Academic Research.*

National Institutes of Health (NIH). 1989. *The Status of Biomedical Research Facilities: 1988.* Bethesda, MD: NIH.

National Research Council (NRC), Committee on National Statistics. 1989. *Surveying the Nation's Scientists and Engineers: A Data System for the 1990s.* Washington, DC: NRC.

National Science Board (NSB). 1987. *Science & Engineering Indicators—1987.* NSB 87-1. Washington, DC: Government Printing Office.

———. 1982. *University-Industry Research Relationships.* Fourteenth Annual Report of the National Science Board. Washington, DC: NSF.

National Science Foundation (NSF). 1989a. *Federal Funds for Research and Development: Fiscal Years 1987, 1988, and 1989.* NSF 89-304. Washington, DC: NSF.

———. 1989b. *National Patterns of R&D Resources: 1989.* NSF 89-308. Washington, DC: NSF.

———. 1989c. *Academic Science/Engineering: R&D Funds, Fiscal Year 1987.* NSF 89-311. Washington, DC: NSF.

———. 1989d. "Modernizing Academic Research Facilities: A Comprehensive Plan." Washington, DC: NSF, Research Facilities Office.

———. 1988a. *Scientific and Engineering Research Facilities at Universities and Colleges: 1988.* NSF 88-320. Washington, DC: NSF.

———. 1988b. *Academic Research Equipment in Selected Science/Engineering Fields: 1982-83 to 1985-86.* SRS 88-D1. Washington, DC: NSF.

———. 1988c. *Federal Support to Universities, Colleges and Selected Nonprofit Institutions: Fiscal Year 1987.* NSF 88-330. Washington, DC: NSF.

———. 1987a. *Infrastructure: The Capital Requirements for Academic Research.* PRA Report 87-3. Washington, DC: NSF.

———. 1987b. *A Guide to NSF Science/Engineering Resources Data.* NSF 87-308. Washington, DC: NSF.

Office of Technology Assessment (OTA). 1986. *Research Funding as an Investment: Can We Measure the Returns?* Washington, DC: Government Printing Office.

Schubert, A., W. Glänzel, T. Braun. 1989. "World Flash on Basic Research. Scientometric Datafiles. A Comprehensive Set of Indicators on 2649 Journals and 96 Countries in All Major Fields and Subfields 1981-1985." *Scientometrics* 16: 3-478.

Teich, A.H., and K.M. Gramp. 1988. *R&D in the 1980s: A Special Report.* Washington, DC: American Association for the Advancement of Science.

U.S. Patent and Trademark Office. 1989. *Technology Assessment and Forecast Report: All U.S. Universities, 1/1969-12/1988.* Washington, DC: U.S. Patent and Trademark Office.

Young, P.R. 1989. "Periodical Prices, 1987-1989 Update." *Serials Librarian* 17(1-2): 11-37.

Young, P.R., and K.H. Carpenter. 1989. "Price Index for 1989: U.S. Periodicals." *Library Journal* 114: 43-49.

Chapter 6
Industrial R&D and Technology

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Industrial R&D and Technology

HIGHLIGHTS

- *Expenditures for industrial research and development (R&D) are growing, but this growth is beginning to slow.* Total industrial expenditures for R&D are estimated at $95.4 billion in 1989; this is 72 percent of all R&D expenditures in the United States. From 1980 to 1985, the average annual increase in industrial R&D performance was 6.3 percent in constant dollars. However, increases averaging only 1.8 percent per year are estimated from 1985 to 1989. (See pp. 129-31.)

- *Private industry has funded more than one-half of all industrial R&D every year since 1968, and since 1979 has funded about two-thirds of the total.* From 1980 to 1985, company funding increased by an average of 5.4-percent per year in constant dollars. There was essentially no growth from 1985 to 1986. From 1986 to 1989, estimates are that company funding went up by only 2.3 percent per year. (See pp. 129-31.)

- *The rate of increase of Federal funds for industrial R&D is slowing after a period of rapid growth.* From 1980 to 1985, Federal funds for industrial R&D increased at a rate of 8.1 percent per year in constant dollars. The growth from 1985 to 1986 was less than 1 percent. From 1986 to 1989, only a 2.1-percent annual increase is estimated. (See pp. 129-31.)

- *Between 1980 and 1986, R&D expenditures increased especially rapidly in high-tech manufacturing industries.* The growth rate was 5.8 percent per year in constant dollars. In other manufacturing, growth was 4.4 percent per year; in nonmanufacturing, it was 2.0 percent per year. Growth was especially rapid in chemicals and allied products and in electrical equipment. (See p.131.)

- *The Federal Government supports an especially high share of industrial R&D in defense-related industries, such as aircraft and missiles (74.5 percent Federal) and electrical equipment (42 percent Federal).* From 1980 to 1986, Federal support grew especially rapidly—by 9.6 percent per year in constant dollars—in the communication equipment industry. In machinery, including computers, the growth of Federal funding was 9.2 percent per year. These industries are also highly defense-related. (See p. 131.)

- *The number of U.S. patents granted to Americans has reversed its decline and has been increasing since 1983.* After a decline averaging 2.1 percent per year from 1969 to 1983, in terms of date of patent application, there was a 5.4-percent per year increase from 1983 to 1988. However, foreign patenting increased by 9.1 percent per year from 1983 to 1988. (See pp. 132-33.)

- *The share of U.S. patents granted to foreigners rose to 48 percent in 1988.* The Japanese share was 21 percent, and is still growing rapidly; it was 10 percent in 1978. (See pp. 132, 135, 139.)

- *Japanese patenting in the United States emphasizes certain specific technology fields that are commercially important, such as photocopying, information storage and retrieval, photography, motor vehicles, and typewriting machines.* American inventors give especially low emphasis to those fields, but do emphasize chemical fields like biochemistry, petroleum, and pharmaceuticals. (See pp. 136-38.)

- *The share of U.S. patents going to U.S. nationals declined in most broad industries from 1978 to 1988.* The share granted to Americans fell from 64 to 44 percent in office, computing, and accounting machines (including computers); and from 63 to 43 percent in motor vehicles. The Japanese share has grown in all broad industries, particularly in office, computing, and accounting machines. (See p. 139.)

- *Citations from U.S. patents to earlier U.S. patents suggest that the patents received by Japanese and U.S. corporations are most frequently cited and therefore may be of especially high quality.* Patents granted to inventors from other countries and those owned by U.S. individuals or the U.S. Government are less frequently cited. (See pp. 139-41.)

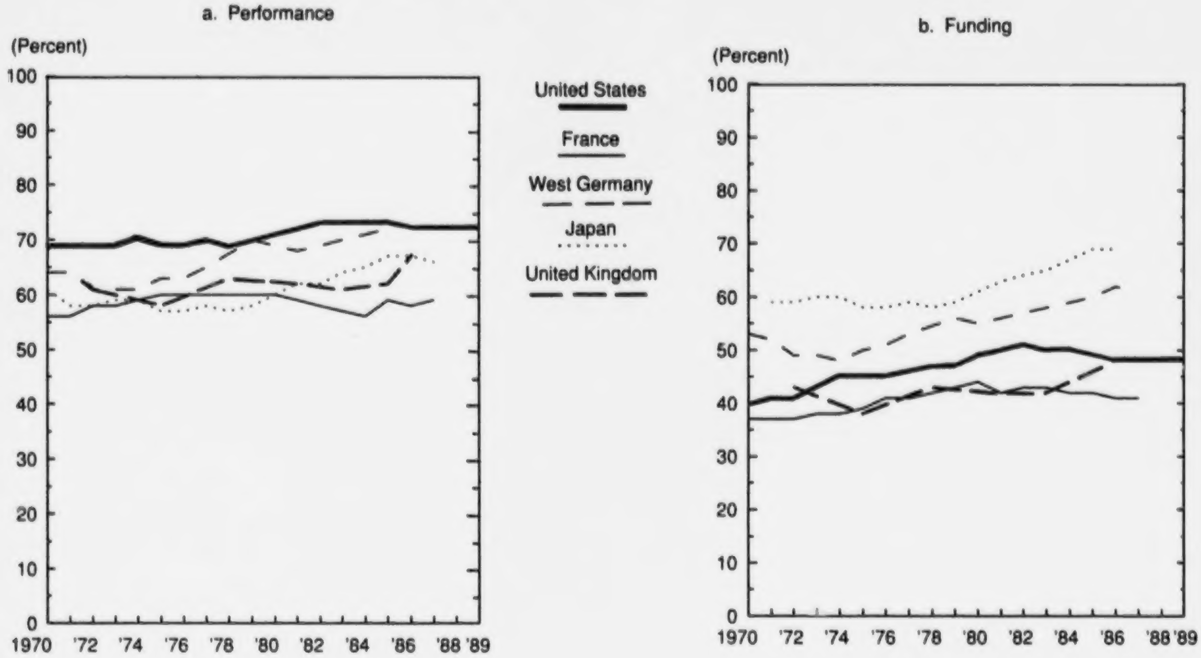
- *Small business establishments operating in high-technology fields prospered substantially more than those operating in other fields during 1980-86.* Employment in small business establishments operating in high-tech fields grew at more than double the rate of small business establishments in the entire U.S. economy. Employment in technology-related industries grew by 28 percent during this period, while employment in all small businesses grew by 11 percent. (See pp. 142-43.)

- *Small high-tech establishments exhibited a stronger tendency to leave the small business category through growth or mergers than did small non-high-tech establishments.* Also, small high-tech manufacturing establishments were more likely to grow or merge out of the small business category than were small business establishments performing high-technology services. Manufacturing businesses that operated in the communication equipment and electronic components industries were most likely to make the transition. (See p. 143.)

- *The pool of capital managed by venture capital firms grew dramatically during 1978-87.* Venture capital is an important source of funds used in the formation and expansion of small high-tech companies. In 1987, the pool of capital was eight times as large as it was in 1978. Pension funds were a growing source of new money committed to venture capital firms. (See pp. 144-45.)

- *Small businesses continue to play an important role in the biotechnology industry, accounting for 95 percent of all firms operating in the field during 1988.* There are indications that the industry's rapid growth during the early 1980s may be slowing down. Since 1985, there has been a steady decline in new biotech firms. During 1987, capital raised through initial public offerings for biotechnology firms declined by 50 percent compared with that raised during 1986. (See p. 145.)

Figure 6-1.
Industry funding and performance of R&D, as a percentage of total R&D, in selected countries



See appendix table 6-1.

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Industry is, in many respects, the most important sector in any analysis of science and technology (S&T). In the United States, 72 percent of all research and development (R&D) expenditures are for R&D performed in industry. (See figure 6-1a.) Among other large industrialized market-economy countries, West Germany has a similar share of R&D *performed* by industry. Japan and the United Kingdom have somewhat lower shares (66 or 67 percent), while in France about 59 percent of national R&D expenditure is in industry. The share of R&D performed in industry has actually increased in West Germany (since the early 1970s) and in Japan (since the middle 1970s).

Private industry is the *source* of 48 percent of all funds spent for R&D in the United States,[1] with the rest provided by the Federal Government. Nearly all industry funding is for R&D that will be performed in industry itself.[2] Of the other four countries shown on figure 6-1b, Japan and West

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[1] This number actually includes funding from all non-Federal sources, including state and local governments, but nearly all of this is in fact private funding.

[2] About 1 percent is spent on university research, and almost 1 percent on research in nonprofit institutions. For a discussion of industry support for R&D in colleges and universities, see chapter 5.

Germany have a considerably larger share of their national R&D funds coming from private sources than the United States has. France and—until recently—Britain have less of their R&D funded by industrial sources.[3] In all five countries, the trend since the early 1970s seems to be for increased shares of industrial support of R&D. In the United States, however, the trend has reversed slightly, with lower shares of private support since the peak year in 1982. This is due primarily to the buildup of Federal R&D for defense in the 1980s.

This chapter discusses private and Federal funding of R&D in U.S. industry. Industrial R&D is the principal source of technological developments that benefit the entire economy. Some of these benefits are seen in the production of new technical inventions. These are discussed in terms of the patents granted to Americans and also to foreign inventors. Another aspect of industrial technology is the formation and growth of high-tech small companies; these are the subject of the last section of this chapter. U.S. industry's experience in the international marketplace for high-tech products is discussed in chapter 7. The employment of scientists and engineers in industry is treated in chapter 3.

EXPENDITURES FOR RESEARCH AND DEVELOPMENT IN U.S. INDUSTRY

Trends in constant-dollar funds spent on industrial R&D are indicators of the level of R&D activity in U.S. industry. Funds for industrial R&D come almost exclusively from two sources: private industry itself and the Federal Government.[4] Total current-dollar expenditures for industrial R&D have increased markedly in the 1980s, with $90.6 billion estimated for 1988 and $95.4 billion estimated for 1989. (See figure 6-2.) This increase repre-

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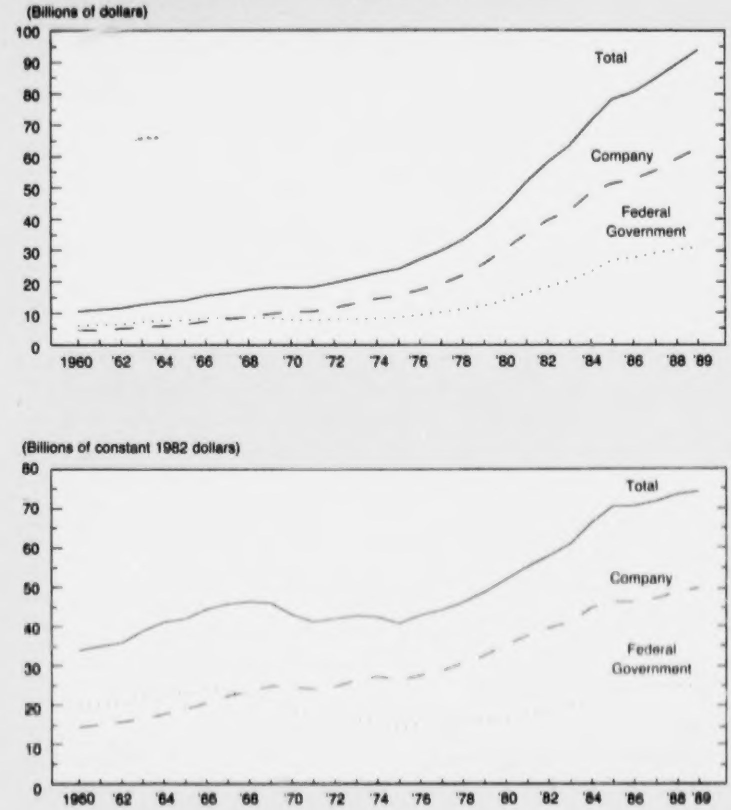
[3] For France and Britain, the data shown include R&D funding provided by public, as well as private, corporations. Thus, the level of private funding for industrial R&D is lower than is shown on figure 6-1.

[4] Some companies perform independent research and development (IR&D), i.e., in-house R&D intended to better prepare the companies to bid on National Aeronautics and Space Administration or Department of Defense projects. Some of these expenditures are later reimbursed by the agency as overhead charges allocated to contracts. In this chapter, IR&D expenditures are counted as company-funded R&D.

Figure 6-2.
Expenditures for industrial R&D, by source of funds



See appendix table 6-2.

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sents an 8.8-percent annual growth rate from 1980 to 1989 in current dollars. In constant-dollar terms, total R&D funding in industry has risen every year from 1975 to 1989. From 1980 to 1985, the growth rate was 6.3 percent per year. This rate has slowed in recent years, however: it was only 0.9 percent per year from 1985 to 1987. An increase of only 2.9 percent is estimated from 1987 to 1988, and only 1.3 percent from 1988 to 1989.

Trends in Company and Federal Funding

The share of industrial R&D funding coming from the companies themselves increased steadily from the early 1960s until 1980. (See figure 6-2 and appendix table 6-2.) From 1980 until 1986, this trend was reversed as the military buildup led the Federal contribution to increase more rapidly than the private contribution. Since 1986, preliminary data and estimates suggest that the trend has begun to return to the older pattern, with private financing increasing a little more rapidly than Federal financing.

More specifically, from 1963 until 1980, private funding for industrial R&D increased at an average rate of 4.6 percent per year (in constant dollars), while Federal support decreased by 1.8 percent per year. From 1980 to 1985, company support continued its increase at a rate of 5.4 percent per year, but Federal support went up by 8.1 percent per year on average. From 1985 to 1986, there was essentially zero growth in company-funded R&D, while Federal funding went up less than 1 percent.

After 1986, the overall growth in funding seems to have resumed, but at a slower rate than in the early 1980s. From 1986 to 1989, estimates are that company funding went up by only 2.3 percent per year, while Federal funding went up by 2.1 percent per year. Most of this Federal funding increase was from 1986 to 1987; after that, estimates are for sharply decreasing rates of Federal growth. As a result, company funds were 42 percent of all industrial R&D funding in 1963, 68 percent in 1980, 66 percent in 1986, and an estimated 66 percent in 1989.

The very slight increase in Federal support in the last few years is largely because of concern over the Federal budget deficit. In the case of private industry, the relatively low rate of increase of R&D funding has been attributed to (1) relatively small increases in sales and profits, (2) greater emphasis on cost reduction programs, and (3) closer ties between R&D and manufacturing operations, as well as (4) the increase in corporate mergers.[5] Other analyses indicate that mergers and acquisitions in expanding markets are accompanied by increases in R&D; in declining markets, reductions of R&D are more likely to result.

R&D Expenditures in Individual Industries

Individual industries show very different trends in both their R&D expenditures and in the sources of support of those expenditures. It is helpful to divide industries into three general groups: high-technology manufacturing, other manufacturing, and nonmanufacturing.[6] (See figure 6-3.)

High-tech manufacturing industries accounted for 74 percent of industrial R&D expenditures in 1986, up from 72 percent in 1980. Other manufacturing industries accounted for 23 percent. Nonmanufacturing (including services) accounted for only 3 percent. However, innovation in the service industries is sustained by R&D-based products introduced by manufacturing industries, as well as by R&D within those industries themselves. From 1980 to 1986—a period of economic slowdown followed by recovery—total industrial R&D rose by an average of 5.3 percent per year in constant dollars. During this time, R&D within the three industry groups increased as follows:

- High-tech manufacturing—5.8 percent per year,
- Other manufacturing—4.4 percent per year, and
- Nonmanufacturing—2.0 percent per year.

Growth was especially rapid in the high-tech manufacturing industries chemicals and allied products and electrical equipment. (See appendix table 6-3.)

Certain industries receive especially large portions of their R&D support from Federal sources. (See text table 6-1.) This is particularly true in aircraft and missiles and in electrical equipment, which are of special military importance. For example, electronics are an increasingly important component of air weapons systems. Nonmanufacturing industries as a group also have a large share of their R&D funding contributed by the Government. This is the only group to show a clear increase in the Government's share of R&D funding since 1980.

While total Federal support for industrial R&D increased at an average rate of 6.9 percent per year (in constant dollars) from 1980 to 1986, the increase was much more rapid in some industries. In particular, it was 9.6 percent per year in communication equipment, 9.2 percent per year in machinery (including computers), and 7.7 percent per year in all nonmanufacturing. (See appendix table 6-4.) On the other hand, Federal funding of chemical industry R&D declined by 10.8 percent per year.

Company funding for industrial R&D increased by 4.5 percent per year from 1980 to 1986 in constant dollars. (See appendix table 6-5.) The fastest increases were in chemicals and allied products (7.6 percent per year) and in electrical equipment (6.4 percent per year).

Company funding in high-tech manufacturing industries went up 5.8 percent per year, while it went up 2.5

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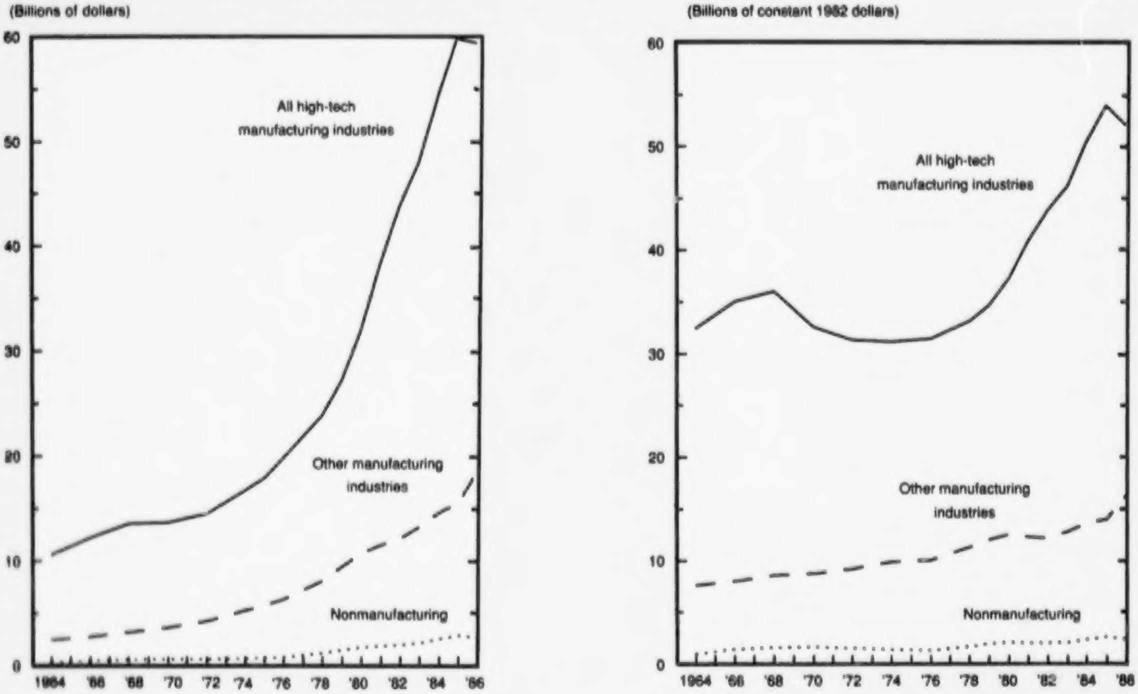
[5] See NSF (1988a) and (1989).

[6] A list of manufacturing industries in the two groups is shown in appendix table 6-3, along with trends in R&D expenditures in each industry. High-tech industries are identified in terms of the ratio of their R&D expenditures to their net sales. The nonmanufacturing industry group here comprises agriculture, forestry, and fishing; mining and construction; transportation, communications, electric, gas, and sanitary services; wholesale and retail trade; finance, insurance, and real estate; computer and data processing services; research and development laboratories and other miscellaneous business services; medical and dental laboratories; and engineering, architectural, and surveying services. Of course, only some of these report significant R&D expenditures. In the future, it will be possible to report R&D expenditures for some specific nonmanufacturing industries. Throughout this chapter, the 1972 Standard Industrial Classification (SIC) is used.

Figure 6-3.
Research and development expenditures, by industry group



See appendix table 6-3.

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percent per year in non-high-tech manufacturing and actually declined 3.7 percent per year in nonmanufacturing. This is a major departure from the trend in Federal funding. Federal support grew by 5.7 percent, 15.0 percent, and 7.7 percent per year, respectively.

From 1986 to 1988, quite different trends are estimated for company funding. (See appendix table 6-5.) While high-tech manufacturing industries are expected to have maintained a growth rate of 5.0 percent per year in constant-dollar R&D expenditures, a net decline is expected in all other industries combined. Chemicals and allied products and electrical equipment are not expected to have maintained nearly the growth rates of recent years, while machinery (including computers) is expected to have had a very high growth rate of 12 percent per year.

PATENTED INVENTIONS

Industrial R&D produces many benefits for the performing company. One of the main benefits is a stream of new technical inventions that may in turn be embodied in innovations—i.e., in new or improved products, processes, and services. As a measure of the success of U.S. industry in producing new inventions, it would be desirable to be able to count them and show their trend over time. While there is no accepted method for counting inventions as such, the *patents* taken out for inventions can provide an indicator of the rate of invention.[7]

Inventors and Owners of Inventions Patented in the United States

Patents by Date of Grant—General Trends. The U.S. Patent and Trademark Office issues patents to both U.S. and foreign inventors. This discussion is limited to patents actually *granted,* rather than to those only *applied for;* furthermore, it deals only with patents granted by the *U.S.* patent office. In 1988, U.S. inventors received 52 percent of U.S. patents granted, while foreigners received the remaining 48 percent. (See figure 6-4 and appendix table

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[7] Patenting indicators, while instructive and convenient, have some well-known drawbacks. For one thing, many inventions are not patented. This is due in part to laws in different states that provide for the protection of industrial trade secrets. Different industries vary considerably in their propensity to patent their inventions, so that it is not advisable to compare patenting rates across different technologies or industries. In addition, there are various reasons for applying for patent protection, and the inventions patented can vary considerably in quality. (One method of dealing with the question of varying quality, based on patent citations, is discussed later in this section.) These limitations should be kept in mind when using patent counts to represent levels of invention. Nevertheless, patents provide a unique source of information on this subject.

Text table 6-1. Share of R&D funding provided by the Federal Government in selected industries: 1980-86

Industry	1980	1983	1984	1985	1986 (prel.)
	Percent				
Total	31.5	32.4	32.4	34.3	34.5
Chemicals and allied products (SIC 28)	8.0	6.1	2.9	3.4	2.7
Industrial chemicals (SIC 281-2, 286)	15.5	12.9	6.3	7.2	6.1
Drugs and medicines (SIC 283)	NA	NA	NA	0.1	NA
Petroleum refining (SIC 29)	9.7	NA	NA	NA	NA
Rubber products (SIC 30)	NA	NA	NA	NA	27.9
Primary metals (SIC 33)	18.5	35.2	NA	NA	NA
Ferrous metals and products (SIC 331-2, 3398-99)	23.7	NA	NA	NA	NA
Nonferrous metals and products (SIC 333-36)	10.5	NA	9.0	9.6	7.5
Fabricated metal products (SIC 34)	8.9	10.3	8.5	6.7	12.5
Machinery (including computers) (SIC 35)	11.0	13.5	12.6	14.2	13.6
Electrical equipment (SIC 36)	40.8	37.9	38.1	41.2	42.0
Radio and TV receiving equipment (SIC 365)	37.8	NA	NA	NA	NA
Communication equipment (SIC 366)	41.2	36.2	37.4	40.8	42.5
Electronic components (SIC 367)	24.7	17.6	18.5	18.7	18.7
Other electrical equipment (SIC 361-64, 369)	49.0	NA	NA	NA	NA
Transportation equipment (SIC 37)	NA	NA	NA	58.2	56.3
Motor vehicles and motor vehicle equipment (SIC 371)	13.2	10.6	11.1	NA	NA
Aircraft and missiles (SIC 372, 376)	72.1	75.1	76.3	76.6	74.5
Professional and scientific instruments (SIC 38)	18.9	14.4	13.6	14.8	15.6
Scientific and mechanical measuring instruments (SIC 381-82)	25.9	NA	NA	NA	NA
Optical, surgical, photographic, and other instruments (SIC 383-87)	13.3	NA	NA	NA	NA
Nonmanufacturing industries	42.9	46.7	47.0	52.5	59.5

NA = Not available.

See appendix tables 6-3, 6-4, and 6-5.

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6-6.) This is the highest share of U.S. patents that foreigners have ever received.[8]

The peak year for patents granted to Americans was 1971.[9] Patenting declined from that year to 1982 and 1983—i.e., shortly after the 1980-81 recession—and has been increasing fairly rapidly since that time.[10] By 1987, U.S. patenting had again reached the level of the mid-1970s, having increased by 7.3 percent per year from the 1983 low. Foreign patenting in the United States was also experiencing a slight dip in 1983. From 1983 to 1987, it rose at a rate nearly twice that of U.S. domestic patenting—13.2 percent per year.[11]

Interpretations of Trends. These trends are open to various interpretations.

- If a country's domestic patenting is taken as an indicator of its production of inventions, then the production of inventions in the United States declined in the 1970s and has been increasing since 1983.[12] In this view, increases in patenting in the United States by foreign countries may be attributed to the desire to exploit the U.S. market, and not to any increase in inventions by those countries.
- On the other hand, patenting by foreign countries in a large country like the United States may be considered an indicator of the levels of invention in those foreign countries. Under this assumption, the rapid increase of foreign patents in the United States since 1983 suggests a rapid increase in foreign levels of invention.[13]

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[8] A few of these foreign inventors actually work for U.S. concerns. In 1988, 6 percent of the patents granted to foreigners had U.S. corporations registered as their owners. In 1978, this proportion was 8 percent.

[9] This is the peak year for patents classified by date of grant. Granted patents can also be classified by date of application, as discussed in the section "Granted Patents by Date of Application," p. 136.

[10] There is a dip in the number of patents granted to all countries in 1979. This is because the patent office budget was insufficient to print all the patents approved in that year.

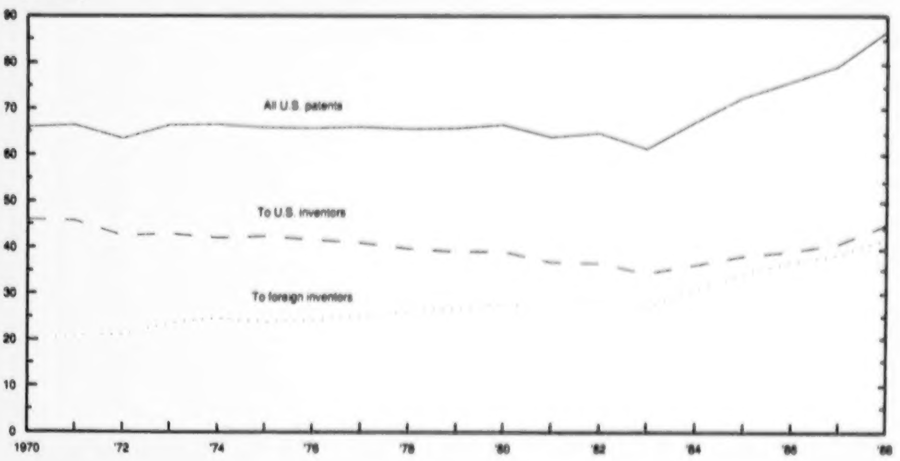
[11] Both U.S. and foreign patenting declined from 1987 to 1988. This is one of many oscillations that appear in patenting data by year of patent grant. It reflects the especially low number of patents that were awarded in 1986 because of budget restrictions at the patent office. This in turn led to a carryover of patents into 1987, and, consequently, an unusually high number of patent grants in that year. The discussion of "Granted Patents by Date of Application" (p. 136) shows that there was no real decline in U.S. and foreign patenting activity from 1987 to 1988.

[12] Many other industrialized countries, excluding Japan, had similar declines in domestic patenting.

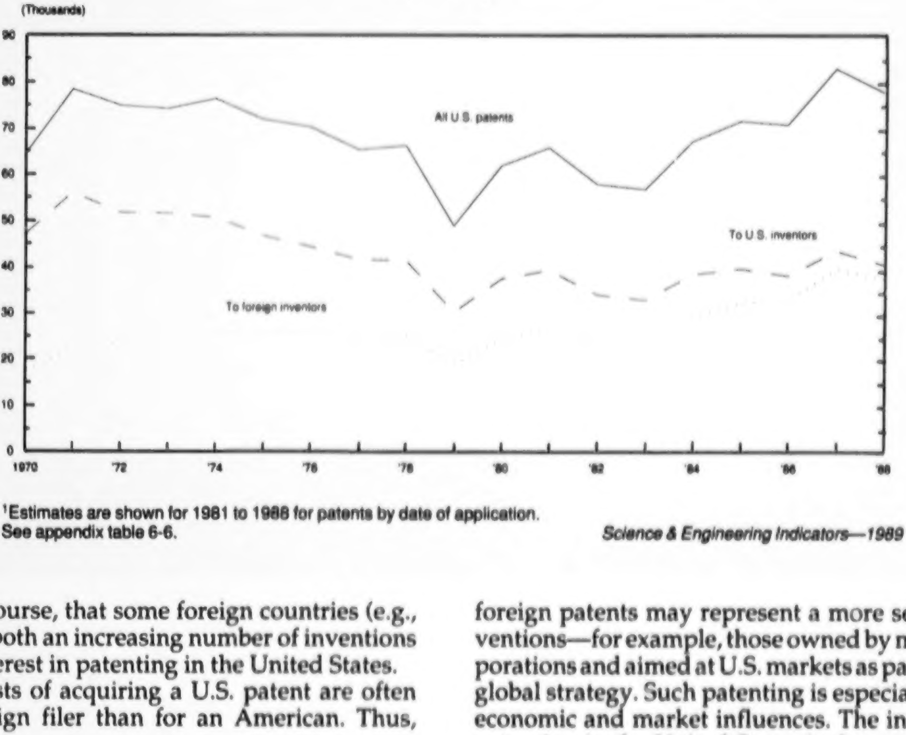
[13] These two interpretations are illustrated by Schiffel and Kitti (1978) and by Pavitt (1985). Data from the *European* Patent Office show that the Japanese share of patents rose from 7.5 percent to 13.0 percent in the short interval from 1983 to 1985. The share of patents granted to Americans remained virtually constant at 22.7 percent. In the same interval, the number of patents granted by the *Japanese* patent office to Americans and to citizens of the contracting states of the European Patent Office was

Figure 6-4.
U.S. patents granted, by nationality of inventor

By date of application[1]



By date of grant



[1] Estimates are shown for 1981 to 1988 for patents by date of application.
See appendix table 6-6.

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It is possible, of course, that some foreign countries (e.g., Japan) may have both an increasing number of inventions *and* a growing interest in patenting in the United States.

Further, the costs of acquiring a U.S. patent are often higher for a foreign filer than for an American. Thus, foreign patents may represent a more selective set of inventions—for example, those owned by multinational corporations and aimed at U.S. markets as part of a company's global strategy. Such patenting is especially responsive to economic and market influences. The increase in foreign patenting in the United States is thus part of the general internationalization of the U.S. economy. In any case, one consequence of the trends discussed here is that more and more of the new technologies available for commercial exploitation in the United States are owned and controlled by foreign corporations.

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nearly identical: both lost a small part of their share, dropping from about 8.2 to 7.3 percent. See U.S. Patent and Trademark Office (1985a), pp. 3 and 41. Thus, Japanese inventors are the only group of the three to show an increasing share of patents in all three patent offices.

Recent research has emphasized also that the trends in the *numbers* of patents are not necessarily the same as the trends in their *quality*. For example, while the number of patents in the United Kingdom, France, and West Germany began to decline in the mid- or late 1960s, the average quality of the patents increased, with the result that the total value of patent rights actually increased.[14] This is related to the finding that a small portion of all patents has most of the total value. Further research is extending these results to more countries and various fields of technology.

Patents Granted to Americans, by Sector. Patents granted to American inventors can be further analyzed according to who owns them. Inventors who work for private companies or for the Government commonly assign ownership of their patents to their employer; self-employed inventors usually retain ownership of their patents. The owner's sector is thus a good indication of the sector in which the inventive work was done. In 1988, 72 percent of patents granted to Americans were owned by *U.S. corporations*.[15] This percentage has varied within a narrow range, i.e., from 74 in 1970 to 70 in 1980. Thus, trends in U.S. patenting are largely trends in patenting by corporations. *U.S. individuals* are the next largest group of owners of patents granted to Americans, and their share has increased somewhat over the past two decades. It began at a relatively low level in 1970 (21 percent), rose to 27 percent in 1980, and was 25 percent in 1988. The *Government's* share of patents has varied from a high of 4 percent in 1976 to a low of 2 percent in 1988.[16] Finally, about 1 percent of patents granted to American inventors are owned by *foreign corporations or governments*.

Patents Granted to Foreign Inventors, by Country. Foreign patenting is highly concentrated in terms of country of origin. (See figure 6-5.) Since 1975, Japan has received more patents than any other foreign country. Japanese inventors have steadily increased their share, receiving 21 percent of all U.S. patents in 1988. West Germany follows with 9 percent, while France and the United Kingdom are next with 3 percent each. Japanese patenting has had especially high growth; it has nearly doubled since 1983, for an annual growth rate of 12.9 percent. In the same

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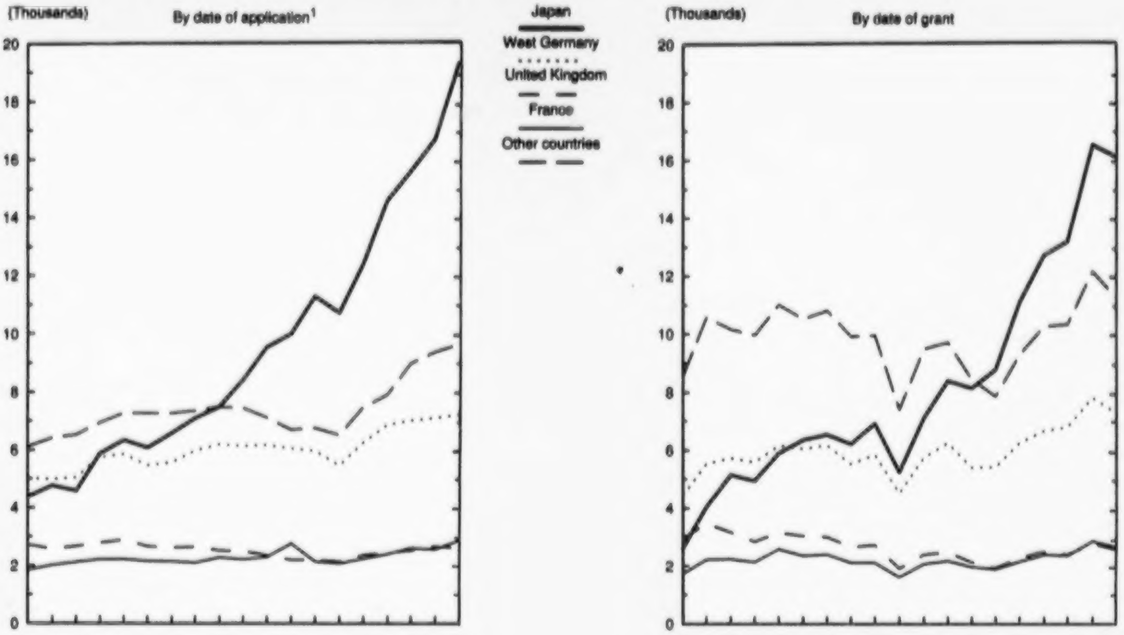
[14] Schankerman and Pakes (1986).

[15] About 2 percent of patents granted to Americans in 1988 were owned by U.S. universities and colleges. These are counted by the patent office as patents owned by corporations. For further discussion of academic patenting, see chapter 5.

[16] In addition to patents, the patent office sometimes awards Statutory Invention Registrations (SIRs), which are publications that are not ordinarily subject to examination and cost less to obtain than patents. They give the holder the right to use the invention and prevent others from patenting it, but do not keep others from selling or using the invention. Government inventors get the majority of SIRs. In 1988, they were awarded 728 patents and 114 SIRs.

Figure 6-5.
U.S. patents granted to foreign inventors, by nationality of inventor



[1] Estimates are shown for 1981 to 1988 for patents by date of application. See appendix table 6-6.

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1983-88 period, other countries' patenting has grown as follows:

- West Germany, 6.1 percent per year;
- France, 7.0 percent per year;
- United Kingdom, 6.0 percent per year; and (for comparison)
- The U.S., 4.3 percent per year.

Granted Patents by Date of Application. Patent data in terms of the year in which the patent was granted show considerable oscillation from year to year. (See figures 6-4 and 6-5.) Much of this is due to fluctuations in the rate at which the patent office processes applications, rather than to any fluctuation in the filing of applications by inventors. To remove the effect of fluctuations in processing rates, granted patents can be allocated to the years in which they were applied for. The application date is roughly 2 or 3 years before the year of grant, and is closer to the time at which the invention actually took place.

By year of application, patenting data show much smoother trends. (See figures 6-4 and 6-5.)[17] In these terms, from the batch of applications filed in 1988, 48 percent of the U.S. patents that will be granted will go to foreign inventors. Japan will receive 22 percent, the West German share will drop to 8 percent, and France and the U.K. will—again—have 3 percent each.

In terms of application date, patents granted to U.S. inventors decreased fairly regularly from 1969 to 1983 at an annual average rate of 2.1 percent. They have increased steadily since the low point in 1983[18] at an average rate of 5.4 percent per year. From 1987 to 1988 alone, they rose by 10 percent, and have again reached the level of the early 1970s.

Japanese patenting has grown by 12.5 percent per year over this period, with a 16-percent increase from 1987 to 1988. Since 1970, annual Japanese patenting in the United States has increased by a factor of 4.4. West Germany's patenting in the United States has increased by 5.7 percent per year from 1983 to 1988, in terms of application date. For France, the increase was 6.7 percent per year, while for the United Kingdom it was 3.9 percent per year. Overall, France has had a substantial increase in its U.S. patenting since 1970, and has overtaken the United Kingdom. (See appendix table 6-6.) These results show that Japan is maintaining the fastest growing rate of filing applications in the U.S. patent office,[19] and will continue in the immediate future to increase its share of patents.

Patent Fields Favored by Inventors From Different Countries

Patent counts give an idea of the amount of inventive activity and output by different countries, but it is also important to know how an individual country's patents are distributed among specific *technical areas*. A large number of patents held by a given country is more meaningful if those patents are in important fields of technology. The best classification system to use in looking at individual fields of patenting is the one that divides patents into the narrowest and most specific classes. This is the U.S. Patent and Trademark Office's own classification system, which contains approximately 370 active classes pertaining to inventions. The patents received by U.S. and foreign inventors in recent years can be compared in terms of these classes.[20]

Comparison of Fields Favored by U.S. and Japanese Inventors. Because of the special interest of U.S.-Japanese comparisons, text tables 6-2 and 6-3 show the areas of greatest and least concentration by American and Japanese inventors patenting in the United States.[21] More extensive data are given in appendix tables 6-7 and 6-8. Comparable data on West German, French, and British patenting in the United States are given in appendix tables 6-9, 6-10, and 6-11. Together, these five countries account for 89 percent of all patents granted in the United States.

To some extent, there is an inverse relationship between U.S. and Japanese patenting. (See text tables 6-2 and 6-3.)[22]

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[17] Since many of the patent applications filed in recent years have not yet been examined by the patent office, it is not known how many of these will ultimately become granted patents. The expected number of granted patents for recent application years can be estimated by multiplying the total number of applications for any year by the recent success rate. Such estimates are used for patenting rates by date of application throughout this chapter.

[18] The data series for patent grants by date of application shows a dip in 1983 for many countries. In fact, the number of applications from many countries was especially high in 1982 and correspondingly low in 1983. This is largely because a new schedule of higher fees was introduced in late 1982, leading to an acceleration of filings in 1982 and fewer in 1983.

[19] Japanese applications also lead to grants more often than do applications from any of the other countries discussed here. For example, an estimated 68.3 percent of the patent applications filed by Japanese inventors in 1985 will lead to patent grants. The percentages for other countries are France, 66.7 percent; West Germany, 65.9 percent; and United States, 59.5 percent.

[20] An earlier report comparing the fields emphasized by U.S. and Japanese inventors in their U.S. patents is Narin and Olivastro (1986). See also Narin and Frame (1989).

[21] The listing is limited to the 130 patent classes that received at least 200 patents, from all countries, in 1988. Thus small fields are not considered. The fields are ordered in terms of the "activity index," which reflects a country's share of the patents granted in a field in 1988. The listings thus show the fields in which a country has high or low *shares* of the patents, rather than the fields in which it simply has high or low absolute *numbers* of patents. Note that "emphasis," as shown on these tables, is a relative term. For example, U.S. inventors "emphasize" certain fields only by comparison with foreign inventors, not by themselves.

[22] Since the United States is the host country, patents granted to American inventors have some special characteristics. In particular, most of the inventors who patent in the U.S. patent office but have no corporate or government affiliation are Americans. Unaffiliated foreign inventors are not likely to apply for American patents because of the difficulty and cost, and because they have little interest in patent protection in the United States. As a result, the data on patenting by Americans reflect a relatively large share of patenting by unaffiliated individuals and a relatively small share of corporate-affiliated patenting. (For example, 73 percent of U.S. patents granted to Americans go to inventors affiliated with corporations, while 96 percent of U.S. patents going to Japanese inventors are owned by corporations.) Unaffiliated individuals tend to patent in fields of little interest to industry, such as fishing, trapping, and vermin destroying, or

Text table 6-2. Patent classes most and least emphasized by U.S. corporations patenting in the United States: 1988

Most emphasized classes	Least emphasized classes
1. Mineral oils: processes and products	1. Fishing, trapping, and vermin destroying
2. Wells	2. Motor vehicles
3. Chemistry: analytical and immunological testing	3. Amusement devices, games
4. Chemistry: molecular biology and microbiology	4. Dynamic information storage or retrieval
5. Catalyst, solid sorbent, or support therefor, product or process of making	5. Photography
6. Error detection/correction and fault detection/recovery	6. Internal combustion engines
7. Semiconductor device manufacturing: process	7. Land vehicles
8. Part of the class 520 series—synthetic resins or natural rubbers	8. Ships
9. Glass manufacturing	9. Amusement and exercising devices
10. Electrical connectors	10. Dynamic magnetic information storage or retrieval
11. Amplifiers	11. Typewriting machines
12. Pulse or digital communications	12. Winding and reeling
13. Multiplex communications	13. Machine elements and mechanisms
14. Surgery	14. Geometrical instruments
15. Electrical computers and data processing systems	15. Photocopying
16. Part of the class 520 series—synthetic resins or natural rubbers	16. Tools
17. Drug, bioaffecting and body treating compositions	17. Chairs and seats
18. Food or edible material: processes, compositions, and products	18. Dentistry
19. Part of the class 520 series—synthetic resins or natural rubbers	19. Radiation imagery chemistry—process, composition, or product
20. Compositions	20. Plastic article or earthenware shaping or treating: apparatus

Note: Listing is limited to U.S. patent office classes that received at least 200 patents, from all countries, in 1988. Classes are listed in terms of the share of patents in each class that are awarded to U.S. inventors and owned by U.S. corporations, beginning with the class in which U.S. corporations have the greatest, or smallest, share.

See appendix table 6-7.

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For example, the Japanese get much more than their share of patents in such technically and commercially important technologies as photocopying, dynamic information storage and retrieval, dynamic magnetic information storage and retrieval, photography, radiation imagery chemistry, typewriting machines, motor vehicles, internal combustion engines, and machine elements and mechanisms. All of these are on the list of technologies in which American corporate inventors get much *less* than their share; this fact is clearly related to the Japanese penetration of U.S. markets in many of these areas.

The inverse relationship between Japanese and U.S. corporate patenting can be partly explained by the fact that in some fields the Japanese get such a large share of the patents that little is left for U.S. corporations and they must necessarily get a small share. Thus, it is important to ask whether there is further evidence that U.S. corporations are weak in these fields. For example, if Japanese patents were eliminated, would U.S. corporations still get low numbers of patents in these areas?

In photocopying, radiation imagery chemistry, and dynamic magnetic information storage and retrieval—all of which are on the list of fields with high Japanese emphasis and low U.S. corporate emphasis—U.S. corporations get more than their share of the non-Japanese patents.[23] Thus, the U.S. corporations show some strength in these areas, though the Japanese show more. On the other hand, in motor vehicles, internal combustion engines, and machine elements and mechanisms (which are also on this list), U.S. corporations did *not* receive their share of the non-Japanese patents.[24] These would appear to be definite areas of weakness for U.S. corporations. In dynamic information storage and retrieval, photography, and typewriting machines, U.S. corporations received about their share of non-Japanese patents. In these three fields, U.S. corpora-

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amusement devices.

Therefore, to put the United States on the same basis as the other countries, text table 6-2 eliminates the patents owned by unaffiliated individuals and shows only patents granted to U.S. inventors affiliated with U.S. corporations.

[23] In 1988, U.S. corporations received 48 percent of all non-Japanese patents. But they received 76 percent of non-Japanese patents in photocopying, 61 percent of those in radiation imagery chemistry, and 60 percent of those in dynamic magnetic information storage and retrieval.

[24] In 1988, U.S. corporations received 26 percent of the non-Japanese patents in motor vehicles, 33 percent of those in internal combustion engines, and 40 percent of those in machine elements and mechanisms.

Text table 6-3. Patent classes most and least emphasized by Japanese inventors patenting in the United States: 1988

	Most emphasized classes	Least emphasized classes
1.	Photocopying	Aeronautics
2.	Dynamic information storage or retrieval	Wells
3.	Dynamic magnetic information storage or retrieval	Ammunition and explosives
4.	Photography	Prothesis (i.e., artificial body members), parts thereof or aids and accessories therefor
5.	Radiation imagery chemistry—process, composition, or product	Bottles and jars
6.	Recorders	Amusement and exercising devices
7.	Typewriting machines	Fishing, trapping, and vermin destroying
8.	Static information storage and retrieval	Static structures, e.g., buildings
9.	Pictorial communication; television	Surgery
10.	Motor vehicles	Beds
11.	Internal combustion engines	Geometrical instruments
12.	Active solid-state devices, e.g., transistors, solid-state diodes	Tools
13.	Machine elements and mechanisms	Hydraulic and earth engineering
14.	Clutches and power-stop control	Stoves and furnaces
15.	Electricity, motive power systems	Mineral oils: processes and products
16.	Electrical generator or motor structure	Cleaning and liquid contact with solids
17.	Registers	Special receptacle or package
18.	Optics, systems and elements	Induced nuclear reaction, systems and elements
19.	Stock material or miscellaneous articles	Receptacles
20.	Metal treatment	Dispensing

Note: Listing is limited to U.S. patent office classes that received at least 200 patents, from all countries, in 1988. Classes are listed in terms of the share of patents going to Japanese inventors, beginning with the class most, or least, emphasized.

See appendix table 6-8.

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tions are at a disadvantage with respect to the Japanese, but not with respect to other foreign patenters.

While Japanese patenting in the United States emphasizes such areas as electronics, photography and photocopying, and motor vehicles, U.S. corporations emphasize patenting in chemical areas, including biochemistry, petroleum, and pharmaceuticals. (See text table 6-2 and appendix table 6-7.) Other areas of emphasis are communications and semiconductor manufacture. Wells and mineral oils—fields highly emphasized by Americans—are among those areas in which the Japanese patent the least, perhaps because of the lack of domestic oil production in Japan.

Over the 10-year period from 1978 to 1988, U.S. corporations have substantially increased their emphasis on molecular biology and microbiology (see appendix table 6-7); these fields are pertinent to the biotechnology industry. Other large increases were in communications, mineral oils, and glass manufacturing. On the other hand, large *decreases* occurred in U.S. relative activity in motor vehicles, dynamic information storage and retrieval, photography, typewriting machines, and photocopying. Not only are these technologies strongly emphasized by Japanese inventors and weakly emphasized by U.S. inventors, but also the U.S. emphasis in these areas has been decreasing in comparison with other countries. In a few of these areas—e.g., photocopying, typewriting machines, and motor vehicles—Japanese inventors have significantly increased their emphasis since 1978. (See appendix table 6-8.)

Fields Favored by Inventors in Other Countries. Data for West Germany, France, and the United Kingdom show each country's different technical emphases. For example, West Germany patents heavily in printing, in chemicals—including fertilizers and plastics—and in ammunition and explosives. (See appendix table 6-9.) There is low activity in photocopying, photography, and recorders (which are Japanese specialties), with an especially large drop from 1978 to 1988 in the German emphasis on photography. West German activity is also low in wells and mineral oils, which are areas emphasized by U.S. corporations.

French patenting emphasizes nuclear technology (which none of the other countries does) and communications, in addition to mechanical technologies like brakes and clutches. (See appendix table 6-10.) The French, like the Germans, also emphasize ammunition and explosives, which is among the least emphasized areas for the Japanese. Again like the Germans, the French do not get many patents in photocopying, an area of Japanese emphasis. Unlike the Germans, the French do not patent much in chemical fertilizers.

The British emphasize hydraulic and earth engineering and power plants. (See appendix table 6-11.) They share the American emphasis on drugs, glass manufacture, and multiplex communications, as well as the French emphasis on aeronautics, which is the field least emphasized by the Japanese. The British, like the Germans and French, patent a great deal in brakes and organic compounds, but not much in photography.

Patenting in Various Industries by Inventors From Different Countries

Rather than using the U.S. patent office's classification system, patents can also be classified according to the Standard Industrial Classification, which allocates patents to the appropriate industries.[25] (See appendix table 6-12.) From 1978 to 1988, the share of U.S. patents going to American inventors dropped from 62 to 52 percent. Except for a slight increase in drugs and medicines, the U.S. share of patents dropped in all of the 16 SIC product fields shown. The drop was especially great in:

- Office, computing, and accounting machines—from 64 to 44 percent;
- Motor vehicles and other transportation equipment—from 63 to 43 percent;
- Communication equipment and electronic components—64 to 48 percent; and
- Aircraft and parts—54 to 41 percent.

In some of these cases, the falloff of U.S. share occurred because other countries were increasing their patenting more rapidly than the United States was. However, there was an actual drop in the total number of U.S. patents from 1978 to 1988 and—more specifically—in the number of U.S. patents in transportation equipment excluding aircraft and in aircraft and parts.

Japan's share of U.S. patents approximately doubled in this period, going from 10 to 21 percent of the total. The Japanese share increased in each of the 16 product fields shown, with an especially large share increase in office, computing, and accounting machines (rising from 15 to 40 percent). Japanese patenting in this field nearly reached the level of U.S. domestic patenting. Large increases in Japanese patenting also occurred in communication equipment and electronic components (from 14 to 30 percent), in textile mill products (from 11 to 26 percent), and in motor vehicles and other transportation equipment (from 11 to 26 percent).

The West German share of U.S. patents increased slightly from 1978 to 1988, with the greatest share increases in motor vehicles and other transportation equipment, aircraft and parts, and nonelectrical machinery. Decreases in share occurred in drugs and medicines and textile mill products. There were no substantial changes in the French shares of patents in various fields; however, there was a broad decline in the shares of patents going to the United Kingdom. The largest share declines for the United Kingdom were in drugs and medicines, textile mill products, and food and kindred products. Again, some of these decreases in share are because other countries are increasing their patenting faster. Still, there were actual declines in the numbers of West German patents in textile mill products and in total U.K. patents, as well as in U.K. patents in textile mill products and food and kindred products.

The trends in patenting by industry are broadly consistent with the patterns discussed earlier in narrow technology fields. For example, the U.S. strength in the pharmaceutical industry is consistent with U.S. emphasis on biochemical and pharmaceutical technologies. The relative U.S. weakness in the office, computing, and accounting machines industry is consistent with U.S. weakness in photocopying, information storage and retrieval, and typewriting machines. Similarly, U.S. weakness in the transportation industry is consistent with U.S. weakness in the motor vehicles and internal combustion engine technologies.

Citations From Patents to Previous Patents

One criticism of the use of patent counts as indicators of the amount of technical invention is that not all patents are equally significant. If patents could be assigned relative levels of technical or economic significance, it might be possible to interpret better the known differences between the numbers of patents received by different countries in different fields. While there is not yet a broadly accepted way of doing this, one attempted method of gauging the values of different patents involves interpatent citations.

The front page of a patent document usually contains references to previous patents. These references are supplied by the patent examiner as part of the examination process. Cited patents show the "prior art," i.e., the previous achievements in related fields of invention that were taken into account in judging the novelty and significance of the present invention. The patents cited in this way are likely to be the most significant ones in a given field; therefore, the number of citations a patent receives from the front pages of subsequent patents can serve as an indicator of its technical importance.[26]

Citations to Patents, by Country. Data are available on the citations that the U.S. patents granted in a given year receive from all subsequent U.S. patents. It is possible to see which countries have the patents receiving the most and the fewest citations, and in which fields. For example, of the 10 countries that receive the most patents, Japan is the one whose patents are most often cited. (See text table 6-4a.) This remains true over the period from 1975 to 1985.[27] American patents are cited second most often, with The Netherlands, the United Kingdom, and West Germany following behind. Thus, this appears to be the order of technical significance of the patents granted to these countries.[28]

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[25] Patenting in these industrial fields was estimated by means of the "Concordance," a computer program maintained by the U.S. Patent and Trademark Office that converts patent counts from the patent office classification system into patent counts in terms of the 1972 SIC system. Patent classes are each associated with the SIC industry that would produce the product or apparatus or would carry out the process steps associated with that class of patents. See U.S. Patent and Trademark Office (1985b), p. 26.

[26] A study of technologically important patents (those connected with innovations that had won the "IR-100" award from *Industrial Research* magazine) showed that, on average, such patents receive twice as many citations as does the average patent. This helps to confirm the validity of interpatent citation as an indicator of patent quality. See Carpenter, Narin, and Woolf (1981). In addition to these examiners' citations on the front of the patent document, there are also citations to earlier patents that the applicant provides within the document. Patents receiving high numbers of examiner citations also tend to receive high numbers of applicant citations. See Carpenter and Narin (1983).

Citations to Patents, by Country and Industry. Since different countries attract citations in different SIC industries, the fields in which a country's patents are more or less significant can be estimated.[29] The fields in which a country's patents are highly cited are often not the same as the ones in which that country receives a large share of patents.[30] For example, patents granted to U.S. inventors in 1980 and 1985 are most highly cited in drugs and medicines and in primary metals and products.[31] While drugs and medicines is a field of outstanding patent activity by U.S. inventors, metals is not. Patents for American inventions receive especially few citations in engines and turbines, in transportation equipment, and in aircraft and parts,[32] all of which are also known areas of weakness in terms of absolute numbers of patents. On the other hand, fields like communication equipment and electronic components and office, computing, and accounting machines, which have dropped greatly in terms of the U.S. share of patents, show average rates of citation with little notable change from 1980 to 1985.[33]

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[27] Text table 6-4 shows a sharp decline in the number of citations per patent from 1975 to 1980, and another from 1980 to 1985. This is because newer patents have had fewer years in which to be cited, not because of any general decline in the quality of patents. Data on citations received per patent are valid as of the end of 1988. Consequently, the data shown for 1985 are especially incomplete.

[28] The frequency with which a country's patents are cited is explained in part by the technical fields in which it receives patents. Interpatent citation is more frequent in some fields than in others, and countries may concentrate their patenting in fields where citation is more frequent or less frequent than the average. Correction should be made for this, since the fields where more interpatent citation occurs are not necessarily fields where patents should be considered more valuable.

The data on text table 6-4 can be adjusted by giving every country the same distribution of patents by SIC field, i.e., the distribution that applies to the United States. If this is done with the 1980 data, the citation frequencies per patent for the different countries are as follows:

- Japan, 3.19;
- United States, 3.09;
- United Kingdom, 2.76;
- The Netherlands, 2.73;
- Switzerland, 2.65;
- Canada, 2.59;
- Sweden, 2.57;
- West Germany, 2.54;
- Italy, 2.50; and
- France, 2.46.

Thus, differences between countries are diminished and there are some changes in the ranking of countries, but Japan remains first and the United States second.

[29] The source for these data is CHI (1989).

[30] Over the list of 55 SIC fields, the correlation coefficient R^2 between numbers of patents and citations per patent is 0.05 or less for each of the 10 countries studied.

[31] These estimates were made by ranking each industry in terms of the citations per patent to U.S. inventors, divided by the citations per patent to *all* inventors. Correction is thus made for different rates of interpatent citation in different fields and also for the lower number of citations per patent in 1985 as compared with 1980.

[32] Patenting data on aircraft and parts are confounded by the difficulty of distinguishing aircraft inventions from those in more conventional transportation technologies, such as motor vehicles. See U.S. Patent and Trademark Office (1985b).

[33] Note again that citation data for 1985 patents are especially incomplete.

Text table 6-4. Citations from U.S. patents to earlier U.S. patents, by country of inventor or sector of owner of cited patents

Year of cited patents	United States	Japan	The Netherlands	United Kingdom	West Germany	Canada	France	Switzerland	Italy	Sweden
	a. Country of inventor									
	Citations per citable patent									
1975	3.91	4.03	3.63	3.63	3.33	3.33	3.09	2.98	2.99	3.24
1980	3.09	3.35	2.90	2.70	2.51	2.50	2.41	2.37	2.34	2.28
1985	1.37	1.84	1.15	1.21	1.15	1.11	1.07	1.10	1.04	1.02

	All U.S. inventors	U.S. corporations	U.S. Government	U.S. individuals	Foreign owners
	b. Sector of owner, for U.S. inventors				
	Citations per citable patent				
1975	3.91	4.15	3.00	3.34	4.13
1980	3.09	3.37	2.41	2.46	3.42
1985	1.37	1.49	1.07	1.02	1.44

Note: Numbers shown will increase, especially those for more recent years, as patents continue to receive more citations.

SOURCE: CHI (1989).

Science & Engineering Indicators—1989

Japanese patents are especially often cited in transportation equipment fields, as well as metal-working machinery, nonelectrical machinery, and refrigeration machinery. Japanese receive relatively few citations in some chemical-related fields, such as soaps and detergents, paints and varnishes, and drugs and medicines; the Japanese share of patents in these fields also tends to be low. On the other hand, Japanese patenting has grown significantly in fields like office, computing, and accounting machines and communication equipment and electronic components. These fields are still not among those most frequently cited for Japanese patents, though citation to them is greater for 1985 cited patents than for 1980 cited patents.[34]

Citations to U.S.-Owned Patents, by Sector of Owner. The patents owned by Americans can be further divided according to the different classes of owners. (See text table 6-4b.) U.S. corporations own the patents that are most often cited, while patents owned by the U.S. Government or U.S. individuals are cited least often.[35] U.S. corporations, in 1975 and 1980, received patent citations as often as Japanese patenters. Since almost all Japanese patents filed in the United States are owned by corporations,[36] it may be more appropriate to compare the citations received by Japanese (and other foreign) patents with those received by U.S. corporation-owned patents. By this measure, U.S. inventors did as well as Japanese inventors in 1975 and 1980. However, the limited data available suggest that this may not be true for 1985.[37] (See text table 6-4.)

Patents granted to U.S. corporations in 1985 were cited especially often in the fields food and kindred products and ordnance, excluding missiles. They were least often cited in railroad equipment and in motorcycles and bicycles and parts.

SMALL BUSINESS IN HIGH TECHNOLOGY

The role of small business within the science and technology system has received greater attention as concern grows about the Nation's competitiveness. Small business is widely believed to be highly innovative—responsible for many of the new products and processes introduced into the economy.[38] The creation and growth of small high-tech companies are thus of particular interest as they contribute to the Nation's ability to develop, adopt, and diffuse new technologies.

This section concentrates on small firms operating in high-technology industries. It covers indicators of the activities of small business in high-tech industry overall, as well as providing more detailed information on the financial environment for small high-tech enterprise.

Throughout this discussion, the following terms are used; these follow conventions used by the U.S. Small Business Administration (SBA):

- *Establishment* or *company*—a business entity that may or may not be part of a larger complex.
- *Firm* or *enterprise*—an establishment that is either a single location with no subsidiary or branches, or the topmost parent of a group of establishments.
- *Small business*—firm with less than 500 employees (those with 500 or more employees are described as medium or large).

The definition of high-tech firms is more complex. For this analysis, those industries identified by the Department of Commerce's DOC-3 definition as manufacturing high-tech products are used. By this definition, a high-tech industry must produce products that have an R&D intensity significantly higher than that of other products. R&D intensity is arrived at with the help of an input-output table that includes both the direct and indirect R&D expenditures attributed to a product as a percentage of net sales.[39]

Characteristics of Small High-Tech Enterprises

Small businesses account for 99 percent of all establishments operating in the United States.[40] Although small businesses operating in the high-tech fields comprise a smaller share of the total than they do in the economy as a whole, they still represent almost 89 percent of all high-tech establishments.[41]

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[34] For 1980 patents, the average Japanese patent has received 1.13 times as many citations as the average world patent. In office, computing, and accounting machines, this ratio is 1.05, and for communication equipment and electronic components, it is 0.99. For 1985 patents, Japanese patents have risen to a citation rate 1.33 times the world average. Patents in communication equipment and electronic components have been cited 1.16 times the world average, and those in office, computing, and accounting machines 1.11 times the world average. Thus, these fields have shared in the rise in citations to Japanese patents, though they still lag behind the average for all fields.

[35] In this case also, the patents with different classes of owners have different distributions by technical field. (Cf. footnote 28.) The 1980 data have again been recalculated using the same distribution, that for the whole U.S., for each owner class. The result is:

- U.S. corporations, 3.32;
- Foreign owners but U.S. inventors, 3.25;
- U.S. individuals, 2.62; and
- U.S. Government, 2.55.

This does not change the ranking of the owner classes, except in the case of foreign owners but U.S. inventors, which represents only a small group of patents. On the other hand, U.S. corporations are now ahead of Japanese inventors for 1980 cited patents.

[36] Additional data from the patent office show that, in 1987, 96 percent of U.S. patents granted to Japanese inventors were owned by "foreign corporations." Virtually all of these corporations would be Japanese. Another 3 percent were owned by foreign individuals, and 1 percent had American owners.

[37] This result is not affected by differences in the U.S. and Japanese distributions of patents by field.

[38] In a 1982 study done for the U.S. Small Business Administration comparing innovation between small and large firms, it was found that small firms produced 2.4 times as many innovations as large firms per employee. See Futures Group (1984); Hanson, Stein, and Moore (1984), pp. 105-28; and U.S. SBA (1988), pp. vii-ix.

[39] Indirect R&D expenditures describe the R&D content of input products. For additional information on DOC-3, see U.S. DOC (1983), pp. 33-37. See also the discussion in chapter 7 for a list of industries included in DOC-3.

[40] See Social & Scientific Systems, Inc. (1989).

[41] It is not surprising that small business accounts for a larger share of operating establishments in the rest of the economy than in the high-tech sector. The identification of high-technology industries is based on reported R&D expenditures. Such expenditures are not commonplace in many of the service industries that make up much of U.S. small business (e.g., restaurants, service stations, grocery stores, medical services, etc.).

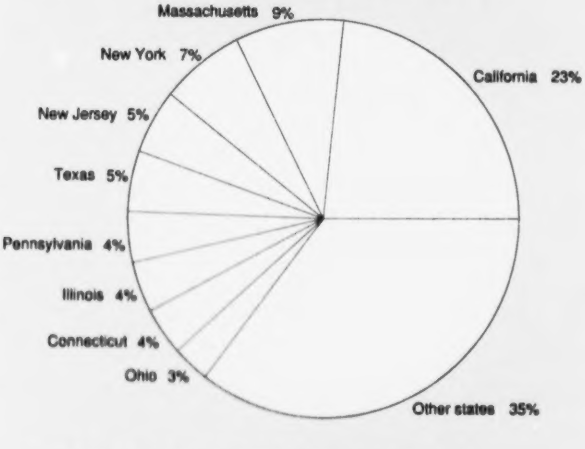
Distribution of Companies by Field. A data base of high-technology companies, the Corporate Technology (CorpTech) Information Services, Inc., database provides additional information about small businesses currently active in high-tech fields.[42] Companies involved in computer software activities and high-tech service companies each account for 17 percent of the companies in the data base. (See appendix table 6-13.) The next most active field, subassemblies and components, accounted for 10 percent of all companies. Small businesses represented:

- 98 percent of the firms active in the computer software field,
- 97 percent of firms active in the photonics and optics field, and
- 96 percent of high-tech service firms and tests and measurements firms.

In fact, in 12 of the 17 high-tech fields categorized in the CorpTech data base, small businesses accounted for at least 90 percent of the total active firms within each category. Clearly, small business drives U.S. activity in high-technology areas.

Distribution of Companies by State. Of the 50 states, California can claim the greatest number of small high-tech firms—23 percent. Massachusetts (9 percent), New York (7 percent), New Jersey (5 percent), and Texas (5 percent) also can boast large concentrations of high-technology businesses. (See figure 6-6 and appendix table 6-14.) While California and Massachusetts spawn many new high-tech companies, the data suggest that as these companies grow larger, many merge or are bought out by large firms located outside of those two states. New York, Pennsylvania, Illinois, and Ohio have a higher concentration of large high-tech firms than small; the opposite is true for California and Massachusetts.

Figure 6-6.
Small firms active in high technology, by state



Note: None of the "other states" exceeds 3 percent.
See appendix table 6-14. *Science & Engineering Indicators—1989*

Company Earnings and Ownership. Over 40 percent of the small high-tech companies in the CorpTech data base have earnings under $2.5 million. Almost 80 percent earn under $25 million. (See appendix table 6-15.)

In this data base, approximately 11 percent of the high-technology companies operating in the United States are under foreign ownership. (See appendix table 6-16.) The United Kingdom has, by far, the largest U.S. presence, followed by Japan and West Germany, which have an almost equal number of companies under their ownership.

Performance of High-Technology Small Business Establishments

An examination of small companies formed and shut down within industries can give some indication of areas of growth—as well as areas of concern—within the U.S. economy. Taken one step farther, such a comparative analysis within high-technology fields can highlight industries that may need greater attention by policymakers.

Small business establishments operating in high-tech fields prospered better than other small businesses during 1981-86. The high-technology community had a net gain of close to 30,000 establishments during that 6-year period, made possible by a formation/closure rate exceeding 2 to 1. Some 339,000 small business establishments were added in other areas of business, but these gains were realized in a far less successful environment; this was evidenced by a formation/closure rate of 1.2 to 1. (See figure 6-7 and appendix table 6-17.)

A larger number of technology-related service establishments were formed during 1981-86 than high-tech manufacturing establishments, but the number of closures was not proportionate. This is in part explained by the lower start-up capital generally needed by service businesses; this permits a greater number of formations and greater longevity due to the lower debt burden. Service companies' major investment is usually in human capital which is more adaptable to the unforeseen tuning often required once the market is entered.[43]

During 1981-86, the greatest number of new small manufacturing establishments were created in the communication equipment and electronic component industries, followed by the industries involving professional and scientific instruments. Computer and data processing companies comprised over one-half of all technology-related service firms formed during the 6-year period examined.

Another useful indicator of the level of activity in an economic sector is *employment*. In 1986, small high-tech

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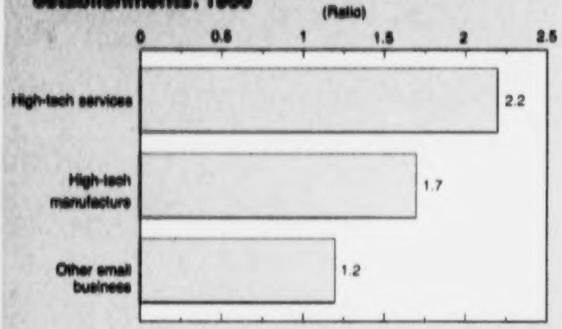
[42] The CorpTech data base attempts to be all-inclusive, but—by CorpTech's own estimate—includes only about 50 percent of the total. When prospective companies are identified, they are sent questionnaires covering their size, status (private or public, independent, subsidiary, or joint venture), year formed, and product groups in which they are active. The version of the data base used in this report (version 3.3, March 1989) includes over 30,000 companies.

[43] For a general discussion of the growth of S/E employment in services and manufacturing sectors, see chapter 3.

Figure 6-7.
Formation/closure ratio for small business establishments: 1986



See appendix table 6-17. *Science & Engineering Indicators—1989*

manufacturing establishments employed more than 739,000 people, up 23 percent from about 600,000 in 1980. (See appendix table 6-18.)

In three technology-related service industries (computer and data processing services; engineering, architectural, and surveying services; and noncommercial educational, scientific, and research organizations), 782,000 people were employed by small business establishments in 1986, compared to 544,000 in 1980—an increase of 44 percent. Employment at technology-related service companies grew faster than in high-tech manufacturing companies: this is more a function of the new service establishments formed during this time than expansion at existing establishments.

A comparison of the gains in employment made in high-tech industries relative to the rest of the economy provides some perspective on their success. (See appendix tables 6-18 and 6-19.) Employment in the technology-related industries overall was 28 percent higher in 1986 than in 1980, while total private sector employment grew by about 11 percent. Concurrently, employment in small business establishments in the technology-related industries grew by 33 percent, while employment in all small businesses grew by 11 percent. The average annual rate of growth in high-tech small business employment during 1980-86 is more than twice the rate of growth in small business employment in the entire U.S. economy.

Despite the gains in numbers employed by small high-tech companies, these companies still account for a substantially lower share of total high-tech employment than is accounted for by small businesses in the U.S. economy as a whole. In 1986, small business establishments accounted for 35 percent of all employment in manufacturing industry in the United States,[44] and about 50 percent of employment in the private sector as a whole. Small high-tech establishments employed 17 percent of total high-tech manufacturing employment and 26 percent of employment at all technology-related establishments during that year.

However, an examination of the new companies formed during 1980-86 suggests that this could change. For each new technology-related small business establishment formed during this period, another eight workers (on average) were employed—compared with seven workers at all other small businesses. Even more encouraging for proponents of high-tech business development is that each new high-tech manufacturing small business establishment added 16 workers on average. The net gain (formations minus closures) in high-technology manufacturing establishments numbered over 6,000 workers, with an average employment of 15.

The apparent vitality of the small high-tech business sector is even more striking when it is considered that some of the businesses that were counted as high-tech small business establishments in 1980 were counted as large businesses by 1986, due to either their growth or their merger with or purchase by other firms. By 1986, 1,195 establishments in the technology-related industries—formerly counted as small businesses in 1980—lost that status either because of internal growth or because merger and acquisition activity had made them parts of larger enterprises. (See appendix table 6-20.) These establishments represent approximately 3 percent of the small establishments that were still operating in technology-related fields in 1986. When viewed against the experience of non-high-tech establishments during 1980-86, small firm establishments in high-tech industries grew out of the small business classification at close to twice the rate of like-sized businesses operating in non-high-tech industries.

The tendency for small high-technology businesses to become medium or large varies considerably among industries. High-technology manufacturing establishments were more likely to grow or merge into large businesses than establishments performing high-tech services; these manufacturing establishments accounted for 55 percent of all technology-related establishments that changed size status, but 67 percent of the gain in employment.

Manufacturing companies that operate in the communication equipment and electronic components industries showed the strongest tendency to leave the small business classification, followed by those companies producing professional and scientific instruments and office, computing, and accounting machines.

Computer and data processing service companies showed a surprising movement out of the small business category, accounting for 289 of the 540 technology-related service companies that expanded and over 23 percent of the employment gains. Technology-related service companies tend to behave like manufacturing companies as they achieve long-term success, they expand and solidify their presence through expansion and merger.

Consequently, if those companies that grew out of the small business classification were included in the examination of the employment gains by high-tech small business establishments during 1980-86, it would show even greater success.

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[44] See U.S. SBA (1988), p. 62.

Venture Capital and High-Technology Enterprise

The growth of small businesses and the introduction of new products require access to pools of capital. Compared to larger firms, small businesses—particularly new firms that seek to develop and exploit a new technology—are handicapped by lack of a financial track record and by narrowness of business activities. These factors combine to make it difficult for a firm to secure traditional financial support, i.e., obtain bank loans or sell equity in the stock markets. In the United States, the need for financing for small innovative firms has been at least partially met by a variety of funding mechanisms. These include an active venture capital industry (described below), small-equity markets—such as the NASDAQ listings and markets made by individual stock brokerages—and other financing systems, such as personal funds, funds from wealthy families and individuals, and trust funds.

Venture capitalists make investments in small and young rapidly growing companies that may not have access to public or credit-oriented institutional funding. Their investments may be divided into two classes:[45]

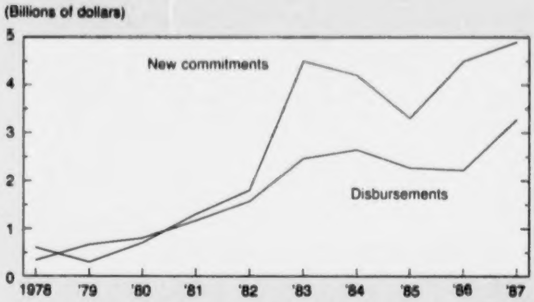
1. *Early stage investments* support the entrepreneur or inventor up through initial commercial manufacturing and sales.
2. *Later stage financing* supports firms that are producing and shipping, but are not yet able to finance substantial expansions and investments in plant. Later stage financing is typically geared toward the sale of stock to the public, known as the initial public offering (IPO).

Most venture capital investments are equity-related, either through direct purchase of stock or through options and other equity-related arrangements. These investments usually emphasize long-term (5- to 10-year) opportunities, and involve the investors closely with the operations of the capital recipient, frequently through participation on the board of directors.

The pool of capital managed by venture capital firms grew dramatically during the 1978-87 period as venture capital emerged as a strong source of finance for small innovative firms. (See figure 6-8 and appendix table 6-21.) In 1987, capital managed by venture capital firms totaled $29 billion; this was eight times the amount available in 1978. During 1983, the total pool of capital grew by 59 percent as a result of a sharp increase in net new private capital commitments. The next 4 years followed the lead set in 1983 and the momentum of the Nation's economic recovery. From 1982 to 1987, the pool grew at more than twice the average annual rate of the previous 4 years.

Faced with declining rates of return in the more traditional investment instruments, pension funds looked to the equity markets for better earning potential and became the source of much of the new venture capital resources.[46] Pension-sourced money committed to venture capital firms grew at a compound annual rate of 64 percent during 1978-86. During the period 1984-86 when foreigners, corporations, and insurance companies reduced funds directed to venture capital firms, pension funds increased theirs at an average annual rate of 24 percent.

Figure 6-8.
Venture capital commitments and disbursements: 1978-87



See appendix table 6-21. *Science & Engineering Indicators—1989*

During the last 5 years studied, new capital commitments exceeded disbursements by the venture capital industry, even when debt financing and leveraged buyout financing are taken into account. Thus, there is apparently a surplus of venture funds seeking outlets in new or expanding innovative firms. But the venture capital industry is highly sensitive to changes in both the economy and the political environment (e.g., treatment of long-term capital gains). For example, if data were available on a quarterly basis, there would most likely be a sharp decline during the fourth quarter of 1987 and during 1988 following the market crash on October 19, 1987.

Throughout the period 1984-87, firms producing computer and computer-related products received the largest—albeit declining—share of both early and later stage investments. Other industries that received substantial venture capital investments were the communications industries and those producing electronic components and other electronic products (including instruments).

IPOs are another indicator of new firms' financial development. At this stage, a firm is presumably well enough established—either through access to superior technology or through actual production and sales capability—that it can raise money through the stock market. Funds raised in this manner increased erratically during the 1984-87 period. (See appendix table 6-23.) IPOs generated $478 million for small firms in 1984 and $345 million in 1985; they then jumped to $1.4 billion in 1986 before dropping back to $1.2 billion in 1987.

High-tech industries met with varying degrees of success with IPOs. The computer and computer-related industry received the bulk of such investment reported in 1984—54 percent of all venture-backed IPOs generated by small businesses. Its share has declined steadily since then, however, accounting for 25 percent in 1987. During 1987, commercial communications, telephone, and data communication firms were able to attract almost four times the dollars raised the previous year. The "information boom" continues to provide an incentive for investment in firms specializing in products that facilitate the compilation and transfer of data.

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[45] The definitions and discussion used here are based on Venture Economics, Inc. (1988).

[46] See U.S. DOC (1988), p. 54-3.

Small Business and Biotechnology

The biotechnology industry is a particularly good vehicle for analyzing small business in the S&T system. It is an industry that has a large science component, using techniques such as recombinant DNA and hybridomas that are the continuing subject of intensive work in university and private basic research laboratories. Also, it is an industry that—considering its small size—performs a significant and increasing amount of R&D, employing thousands of scientists and engineers.[47]

According to the CorpTech data base, there were 717 companies and 438 independent firms active[48] in the various fields of biotechnology during 1988; of these, 414 would be classified as "small business" using the SBA criterion. The vast majority of the small companies active in biotechnology are privately held businesses. More than half of the companies are involved in either genetic engineering and/or producing equipment for the biotech industry. Before 1980, only 371 biotech companies were formed in the United States—346 have been formed since then.

Small biotechnology companies sometimes look to R&D contracts for revenues and leave the larger firms responsible for bringing the products that evolve to market. For example, small companies have contributed significantly in the development of recombinant DNA drugs, but have most often sold the rights to these products to large firms that have the internal structures in place to bring the product successfully to the marketplace.[49]

While revenues have climbed dramatically over the last few years (from $60 million in 1984 to $500 million in 1987), earnings of billions of dollars are often projected for the early 1990s. With the aging of the populace and the proliferation of the AIDS virus, health care is touted as the field from which biotechnology will derive its greatest revenues over the next couple of years.[50]

Biotechnology (including recombinant DNA, monoclonal antibodies and hybridomas, and other genetic engineering) has received small, but increasing, amounts of venture capital during the years for which data are available, receiving about $63 million in early and later stage investment in 1984 and $206 million in 1987. In 1986, there was a surge of venture-backed IPOs by biotechnology firms, with almost $270 million raised, or 19 percent of the total capital raised in this fashion. In 1987, however, financial resources raised through IPOs by biotechnology firms were cut in half. Firms in most other high-tech fields fared better. (See appendix tables 6-22 and 6-23.) The erratic experience with IPOs is a reflection of the rollercoaster expectations that the marketplace has ascribed to the biotechnology industry.

The 3 years following 1985 have shown a steady decline in new biotech companies. Whereas some of the decline can be attributed as a correction to the past surge in growth, the industry is facing some difficult problems that are also contributing to the slowdown.

The projected market values of biotechnology breakthroughs have fallen short of expectations as the reality of bringing the new products to market encounters cost-adding and time-consuming hurdles such as protracted periods of testing and government scrutiny that can delay market entry. Patent infringements—especially foreign violations—are becoming more commonplace[51] and are siphoning off revenues that could support growth and new research in the industry.

The biotechnology industry provides a microeconomic perspective of small business that has its origin in, and whose continued existence is dependent upon, new science and technology. It is an industry whose products have generated a great deal of interest and controversy in many sectors of society. As the industry matures, it will be interesting to observe whether small companies can continue to prosper in a business environment that is certain to become more litigious and, consequently, more cautious about the industry's outputs.

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[47] R&D performed at firms active in biotechnology increased by over 50 percent during 1984-87, reaching an estimated $1.4 billion in 1987. See NSF (1988b).

[48] "Activity" means either production, sales, or R&D activity in the fields defined by the data base as biotechnology.

[49] U.S. DOC (1988), pp. 22-4 to 22-8.

[50] Ibid.

[51] See Clemens and Boroughs (1988).

REFERENCES

Carpenter, M.P., and F. Narin. 1983. "Validation Study: Patent Citations as Indicators of Science and Foreign Dependence." *World Patent Information* 1983: 180-85.

Carpenter, M.P., F. Narin, and P. Woolf. 1981. "Citation Rates to Technologically Important Patents." *World Patent Information* 1981: 160-63.

Clemens, P.W., and D.L. Boroughs. 1988. "Whose Property Is It Anyway? *U.S. News & World Report* 105, no. 19 (November 14): 50-52.

Computer Horizons, Inc. (CHI). 1989. Special report to the National Science Foundation, Science Indicators Group.

Council of Economic Advisers. 1989. *Economic Report of the President*. Washington, DC: Government Printing Office.

Futures Group. 1984. *Characterization of Innovations Introduced in the U.S. Market in 1982*. Washington, DC: U.S. Small Business Administration, Office of Advocacy.

Hanson, Stein, and Moore. 1984. *Industrial Innovation in the U.S., Survey of 600 Companies*. Boston: Boston University.

Kelly, R.K. 1976. "Alternative Measures of Technology-Intensive Trade." *Staff Economic Report*. Washington, DC: U.S. Department of Commerce, Office of Economic Research.

Milberg, W. 1988. "The Product Line Life Cycle Model of Intra-Industry Trade. *Eastern Economic Journal* XIV, no. 4 (October-December): 389-97.

Narin, F., and J.D. Frame. 1989. "The Growth of Japanese Science and Technology." *Science* 245 (11 August): 600-05.

Narin, F., and D. Olivastro. 1986. "Second Interim Report: Identifying Areas of Leading Edge Japanese Science and Technology." Report submitted to the National Science Foundation, Division of Science Resources Studies. National Technical Information Service Order No. PB87 204095/AS.

National Science Foundation (NSF). 1989. "Modest Increase in Company R&D Funding Estimated for 1989." *Science Resources Studies Highlights*. NSF 89-310. Washington, DC: NSF.

____. 1988a. "Economic Outlook and Corporate Mergers Dampen Growth in Company R&D." *Science Resources Studies Highlights*. NSF 88-311. Washington, DC: NSF.

____. 1988b. "Industrial Biotechnology R&D Performance Increased an Estimated 12 Percent in 1987 to $1.4 Billion." *Science Resources Studies Highlights*. NSF 88-306. Washington, DC: NSF.

____. 1987. *International Science and Technology*. Washington, DC: NSF.

Pavitt, K. 1985. "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems." *Scientometrics* 7: 77-99.

Schankerman, M., and A. Pakes. 1986. "Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period." *The Economic Journal* 96 (December): 1052-76.

Schiffel, D., and C. Kitti. 1978. "Rates of Invention: International Patent Comparisons." *Research Policy* 7: 324-40.

Social & Scientific Systems, Inc. 1989. "Science Indicators-1989 for National Science Foundation." Report submitted to the U.S. Small Business Administration, Office of Advocacy. Washington, DC.

U.S. Department of Commerce (DOC), International Trade Administration. 1988. "Venture Capital." In *1988 U.S. Industrial Outlook*. Washington, DC: U.S. DOC.

____. 1983. *An Assessment of U.S. Competitiveness in High Technology Industries*. Washington, DC: Government Printing Office.

U.S. Patent and Trademark Office. 1985a. *Trilateral Statistical Report: 1985 Edition*. Washington, DC: U.S. Patent and Trademark Office.

____. 1985b. "Review and Assessment of the OTAF Concordance Between the U.S. Patent Classification and the Standard Industrial Classification Systems: Final Report." Washington, DC: U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast.

U.S. Small Business Administration (SBA). 1988. *The State of Small Business: A Report to the President*. Washington, DC.

Venture Economics, Inc. 1988. *Venture Capital Investment and Initial Public Offering Trends: 1987*. Special report to the National Science Foundation.

Chapter 7

The Global Markets for U.S. Technology

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The Global Markets for U.S. Technology

HIGHLIGHTS

- *During the period 1970-86, the United States was consistently the leading supplier of high-technology products in the global marketplace.* But its lead position declined from a 51-percent share held in 1970 to its 42-percent share in 1986. Japan doubled its global market share during this period, rising from 16 percent in 1970 to 32 percent in 1986. (See p. 150.)
- *The United States is the world's largest market for high-technology goods, consuming almost half of the high-tech products sold globally.* While U.S. producers were the dominant suppliers to the domestic market during 1970-86, they gradually and consistently lost market share to foreign producers. (See p. 151.)
- *The United States exports a far lower share of its high-technology products (15 percent of its high-tech production in 1986) than do other industrialized countries (West Germany, 61 percent; United Kingdom, 54 percent; France, 38 percent; and Japan, 22 percent).* Still, the United States was the world's leading exporter of high-tech products until 1986, when it was overtaken by Japan. (See p. 152.)
- *The U.S. trade surplus in high-tech goods declined steadily during the 1980s, and suffered its first trade deficit in 1986.* In 1987, the United States once again registered a small trade surplus in high-technology goods, with U.S. exports of aircraft and related parts leading the way. (See p. 153.)
- *U.S. high-technology manufacturing firms maintain a significantly higher portion of their assets in foreign affiliates (42 percent of total assets) than do other U.S. manufacturers (30 percent).* U.S. manufacturers' foreign affiliates are concentrated in Europe. In addition to equity investments in foreign affiliates, U.S. high-tech multinationals enter into agreements with foreign firms to have them supply parts and components to support production opportunities back in the United States. Data on this aspect, however, remain anecdotal. (See p. 155.)
- *The United States licenses considerably more technological know-how to foreign firms than it buys.* U.S. receipts from the sale of patent licenses to foreigners have been, on average, four times that paid out by U.S. firms for access to foreign technological know-how. Japan is by far the largest customer, accounting for 41 percent of such U.S. revenues in 1987. (See p. 156.)

The global marketplace can be considered the commercial proving ground for a country's science and technology (S&T). It is in the marketplace that technological advances in the form of new products or processes are evaluated.

A major share of the U.S. research and development (R&D) effort is accounted for by private firms using private funds. The presumed goal of these investments in S&T is to develop a technological advantage that can be exploited profitably. Research and development are expensive activities that require firms to commit substantial resources over extended periods of time and to assume the risk should these investments not prove profitable. Private R&D investment, which accounts for about one-half of total U.S. R&D, is ultimately judged by the successes and failures of its outputs—new products and processes.

Private financing of the innovation process depends on firms' access to markets and on their expected success in earning sufficient returns on R&D investments to justify further investment in R&D. Well-functioning markets provide the monetary rewards for "good science and engineering" when these efforts lead to technology that is accepted in the marketplace.

U.S. competitiveness in the global marketplace engenders the widespread concern regarding the ability of U.S. producers both to export and compete against imports in their home market. The U.S. S&T system plays an important role in U.S. competitiveness.[1] Skilled and timely exploitation of emerging technological possibilities clearly contributes to the Nation's competitiveness by generating lower costs and new and better quality products. Examination of U.S. firms' performance in the global marketplace provides useful indicators to identify strengths and weaknesses in the Nation's S&T system.

This chapter brings together several data sets describing the domestic and foreign markets for U.S. technology so as to examine the activities of U.S. firms in the global marketplace—particularly in high-technology areas—and thereby assess the relative strength of U.S. industry in global competition.

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[1] Milberg (1988) argues that an industry's innovativeness is dependent upon progressive R&D expenditures, and that such expenditures should be considered a necessary investment to support its position in the global marketplace.

U.S. COMPETITIVENESS IN THE MARKETPLACE

The large U.S. trade deficits of recent years have focused attention upon the country's international economic competitiveness. In 1986, for the first time ever, the U.S. balance of trade in high-tech goods was negative, prompting increased concern about the role of science and technology in supporting and restoring U.S. leadership in the global marketplace.

The relationship between S&T and market competitiveness is circular: science and technology support U.S. competitiveness in the national and international trading system, and commercial success in the global marketplace provides resources to help support new science and technology.[2] The contribution of research and development and other science and engineering (S/E) activities to the Nation's economic performance is therefore indirectly measured by its success in the global marketplace.

This section discusses "competitiveness," broadly defined as the ability of U.S. firms to sell products in the global market. The analysis draws heavily on data compiled by the Organisation for Economic Co-operation and Development (OECD) and the U.S. Department of Commerce (DOC). OECD compiles data from 25 advanced industrialized countries including the United States, Japan, and the European Community.[3] These data are presented for all manufactured goods and high-tech products.[4, 5]

Researchers have used several methods to identify individual industries or product groups as "research intensive" or "high technology." These methods usually employ some measure of the R&D effort undertaken in the industry or product group, normalized for industry size.[6] In some industries, however, the relevant R&D is performed internally; in others, firms depend upon the innovations of those upstream suppliers that provide input to their production processes.

Both OECD and DOC identify high-tech products as those that have higher ratios of R&D expenditures to shipments than do other product groups. The OECD classification used in this analysis is called "high intensity technology products"; it relies on directly applied R&D expenditures in its calculation and includes those products with above average R&D intensities. Direct R&D expenditures are those made by the firms in the product group. High-technology industries identified by OECD's definition—and their respective international standard industrial classification (ISIC) codes—are:

- Drugs and medicines (ISIC 3522);
- Office machinery, computers (ISIC 3825);
- Electrical machinery (ISIC 383 less 3832);
- Electronic components (ISIC 3832);
- Aerospace (ISIC 3845); and
- Scientific instruments (ISIC 385).

The Department of Commerce definition, also used in this analysis, identifies high-tech products as those products that have significantly higher ratios of direct and indirect R&D expenditures to shipments than do other product groups. Indirect R&D describes the R&D content of input products.

To address this complicated technological structure, DOC uses an input-output table to allocate the applied research and development expenditures of intermediate-goods producers among the final-goods producers. This allocation, when normalized by shipments, permits identification of those groups of products whose total R&D intensity is significantly higher than that of other products. These product groups are known collectively as the DOC-3 high-technology products.[7] DOC-3 industries, and their respective Standard Industrial Classification (SIC) codes, are:

- Guided missiles and spacecraft (SIC 376);
- Communication equipment and electronic components (SIC 365-367);
- Aircraft and parts (SIC 372);
- Office, computing, and accounting machines (SIC 357);
- Ordnance and accessories (SIC 348);
- Drugs and medicines (SIC 283);
- Industrial inorganic chemicals (SIC 281);
- Professional and scientific instruments (SIC 38 excluding 3825);
- Engines, turbines, and parts (SIC 351); and
- Plastic materials and synthetic resins, rubber, and fibers (SIC 282).

---

[2] Dornbusch, Porteba, and Summers (1988) describe a higher propensity by manufacturing firms to invest in research and development than firms in other sectors of the U.S. economy. They point out that "manufacturing companies invest 90 times as large a share of their value added in R&D as do companies in other sectors."

[3] The 25 countries reporting to OECD are: Australia, Austria, Belgium/Luxembourg, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, The Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States, West Germany, and Yugoslavia (Yugoslavia participates in OECD with a special status).

[4] The OECD data are expressed in current U.S. dollars at official exchange rates. Fluctuations in the currency exchange rate and differences in the price levels between each country and the United States can distort cross-country, time-series comparisons for products isolated from foreign competition.

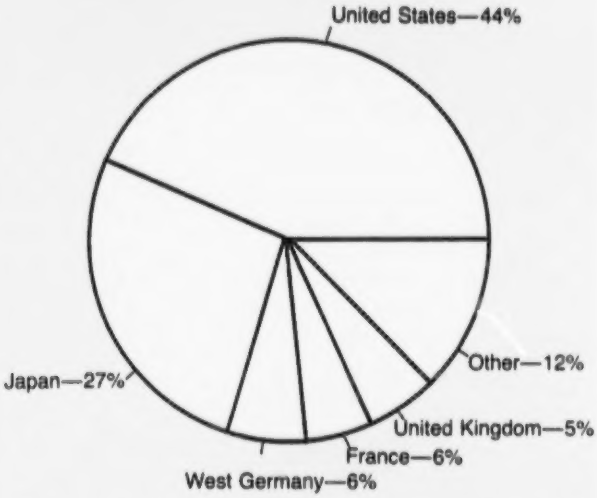
Most manufactured products of the United States and the other OECD countries are exposed to foreign competition in their home markets as well as in foreign markets, thereby reducing the effect currency fluctuations will have on measurement of trade flows. Furthermore, in the following discussion, care has been taken to minimize any distortions caused by the terms of value used. Where distortions cannot be avoided, trends are appropriately qualified.

[5] Data used in this chapter are compiled by government agencies and international organizations. These data benefit from ongoing efforts by the collectors to employ uniform definitions and standards. To account for any remaining slight differences among countries' definitions, concepts, and data collection and reporting practices, attention here is primarily on trends and significant fluctuations in data levels.

[6] R&D expenditures as a percentage of total sales, and scientists and engineers employed in R&D as a percentage of total employment, are two prominent examples of this approach. See Boretsky (1982) and Kelly (1976).

[7] See Davis (1982).

Figure 7-1.
Home markets of major industralized countries as a percentage of the global market for high-tech products: 1986



See appendix table 7-4. *Science & Engineering Indicators—1989*

Comparisons of U.S. production data for "high intensity technology products"— as reported to OECD—with U.S. total shipment data for "high-technology" products—as reported to the Department of Commerce according to the DOC-3 definition— show that OECD data represented 96 percent and 100 percent of DOC-3 data in 1980 and 1986, respectively.

The Global Market for High-Technology Products

The U.S. home market is the largest market for high-tech goods in the world. (See figure 7-1.) Consequently, an assessment of U.S. competitiveness in high-tech goods cannot be evaluated by our trade competitiveness—i.e., a comparison of our exports with our imports—alone. Rather, we must examine the country's ability to sell high-tech products globally and domestically.

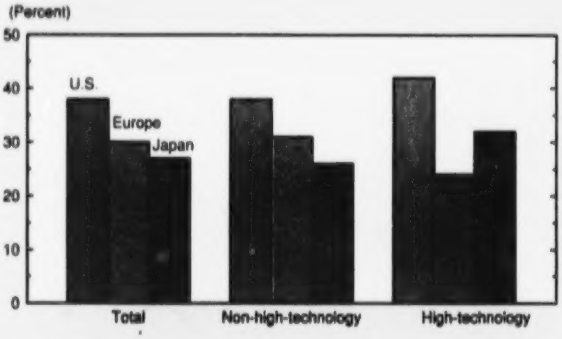
The global market for high-tech products is growing at a slightly faster rate than the market for other manufactured goods. (See appendix tables 7-1 and 7-3.) During the 1970s, high-tech products represented approximately 12 percent of global production of all manufactured goods.[8] During the 1980s, the global market for high-technology goods increased faster than the global market for other manufactured goods, and accounted for 16 percent of total production by 1986.

Over the period examined, 1970-86, the United States clearly reigned as the leading producer of high-tech products, although its position was being challenged. During the 1970s, U.S. global market share declined as Japan, West Germany, and France each increased their production of high-technology products at a faster rate than did the United States. After 1980, the U.S. share increased and—by 1985—approached its previously held level. In 1986, however, U.S. market share fell once again, losing to Japan and West Germany.[9] (See figure O-22.)

Japan's global market share, by contrast, increased during 1970-86—rising from a 16-percent global market share in 1970 to 32 percent by 1986. European producers' global share declined steadily over the period, dropping from a peak of 36 percent in 1975 to a low of 21 percent in 1985. West Germany led European producers in 1986 with a 7-percent market share, compared with 5-percent shares for France and the United Kingdom.[10] (See figure 7-2 and appendix table 7-1.)

As would be expected of major industrialized economies, the U.S., Japan, and Europe have increasingly moved productive resources toward the manufacture of more sophisticated, higher value, technology-related goods and away from more labor intensive products. In 1986, the value of U.S. high-tech products represented 17 percent of total production, up from 13 percent in 1975; high-tech products accounted for 13 percent of Europe's total production in 1986, compared with 10 percent in 1975. (See appendix table 7-3.) But it was Japan that made the greatest

Figure 7-2.
Global market shares for manufactured products: 1986



Note: Production data compiled by OECD are used to estimate the global market for manufactured products.
See appendix table 7-1. *Science & Engineering Indicators—1989*

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[8] Production data, compiled by OECD, are used in lieu of shipment data to estimate the global market for high-tech and other manufactured products. OECD does not collect data on either shipments or changes in inventories; if inventory data were available, shipment data could be calculated from production data. Production data provide a reasonable approximation of worldwide activity, especially for trend analysis.

[9] The fall in the U.S. dollar vis-à-vis the currencies of the other major industrialized countries exaggerates this fall somewhat.

[10] Fluctuations in price levels and exchange rates affect these year-to-year comparisons. If these data could be adjusted to correct for such fluctuations, the relative positions of the United States and Japan would not change, whereas the individual positions of the European countries might realign somewhat. Japan's and West Germany's production are probably overstated to some degree and France's and the United Kingdom's production are probably understated. (See appendix table 7-2.)

transitional leap foward in this respect, pulling even with the U.S. in 1982 and surpassing it thereafter.

The U.S. Market for High-Technology Products

A country's home market is often thought of as the natural destination for its manufactured output. For obvious reasons, marketing at home is easier than marketing abroad—e.g., proximity to the customer, common language, customs, and currency—and other advantages.

But in today's global marketplace, the most competitive product—almost regardless of its origin—wins the sale. When many sellers exist, the most competitive product is determined by its price, quality, and ability to satisfy the customer's needs. Buyers of most goods—but especially of high-technology goods—may weigh these factors differently, but ultimately will choose based on consideration of these elements. Thus, in the absence of prohibitive trade barriers, a country's home market is not a private domain for its native producers, and therefore needs to be included in the equation when examining global competitiveness.

Comparison With Other Markets. As stated earlier, the U.S. market is the single largest market for the world's production of high-tech goods. (See appendix table 7-4.) The U.S. market purchased over half of global production in 1970, with Japan—a distant second—consuming 15 percent. During the 1970s, other countries' home markets grew faster than that of the United States, especially markets in Japan and France: U.S. consumption fell to 41 percent of worldwide consumption, while Japan's market represented almost 20 percent and France as high as 9 percent.

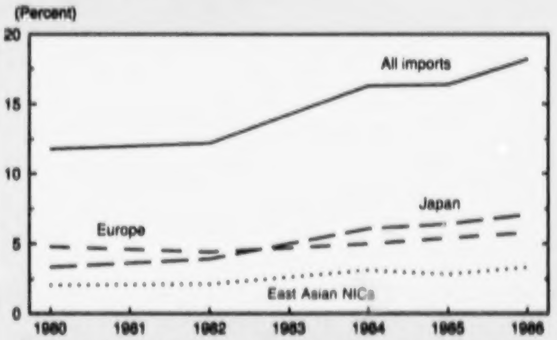
But the 1980s brought with it a realization that U.S. competitiveness in the global market was eroding. One reason for this was deficient manufacturing systems. In response, U.S. industry began to retool its factories and mechanize many tasks formerly done manually. Subsequently, the 1980s saw a resurgence in consumption of high-tech goods in the United States. During 1980-85, the U.S. market for high-technology products increased sharply, which left the relative size of other developed countries' markets to decline in comparison or—as in Japan—fluctuate downward.

U.S. Market. U.S. producers of high-tech products benefitted from having their home market grow at such a pace; shipments within the United States increased over 50 percent during 1980-86. But imports were attracted as well and, encouraged by a strong U.S. dollar, supplied an increasing share of total U.S. high-technology purchases. (See figure 7-3 and appendix table 7-6.)

Imports supplied about 12 percent of U.S. purchases of high-tech products in 1980, rising steadily to 18 percent in 1986. During 1980-86, Japan increased its U.S. market share faster than other suppliers, ultimately doubling its position in the U.S. market for high-technology products. In 1980, U.S. purchases of Japanese high-tech products represented 3.3 percent of total U.S. consumption; by 1986, this had jumped to 7.1 percent.

European suppliers also increased market share during the 1980s, though they were far less successful than Japan.

Figure 7-3.
U.S. imports of high-tech products as a percentage of the U.S. market: 1980-86



Note: East Asian NICs include Hong Kong, Singapore, South Korea, and Taiwan.
See appendix table 7-6. *Science & Engineering Indicators—1989*

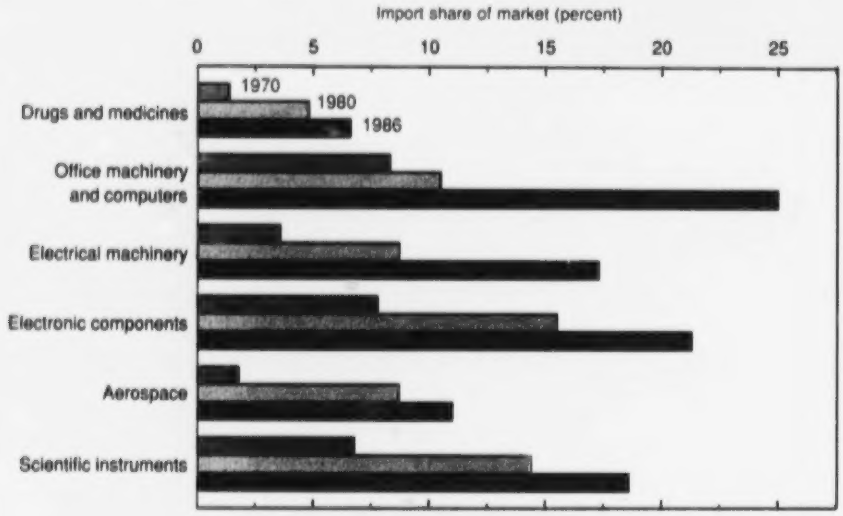
The East Asian newly industrialized countries (NIC)—which include Hong Kong, Singapore, South Korea, and Taiwan—increased their presence in the U.S. market as well, supplying 3.3 percent of U.S. consumption of high-tech products in 1986, up from 2.0 percent in 1980.

A more detailed examination of the U.S. high-technology product market shows foreign producers gaining market share in all sectors. (See figure 7-4 and appendix table 7-7.) By 1986, foreign producers supplied over 20 percent of U.S. consumption of computer products and electronic components. Of all the high-tech sectors, the aerospace industry experienced the greatest rate of increase in foreign competition in the U.S. market as imports' U.S. market share rose from under 2 percent in 1970 to 11 percent in 1986.

Other Countries' Home Markets. The U.S. market is not alone in its increased reliance on foreign technologies. From 1970 to 1986, while European producers of high-tech products steadily increased their shipments to their respective home markets, they still consistently lost market share to foreign suppliers. (See appendix table 7-5.) In fact, European producers' lost home market share was far more dramatic than that experienced by the United States. (See figure 7-5.) For example, in 1970, the United Kingdom's producers supplied 83 percent of their home market for high-technology products; by 1986, they supplied only 46 percent. West German producers' share of their high-tech market was 77 percent; this dropped to 45 percent by 1986. French high-technology producers fared better, but also lost market share to foreign producers as their share declined from 77 percent in 1970 to 62 percent in 1986.

Of the major industrialized countries, only Japan's producers were able to hold domestic market share. In a market that experienced substantial growth during 1970-86, Japanese producers of high-tech products increased shipments to their home market accordingly and thereby

Figure 7-4.
Import penetration of certain U.S. high-tech markets: 1970, 1980, and 1986



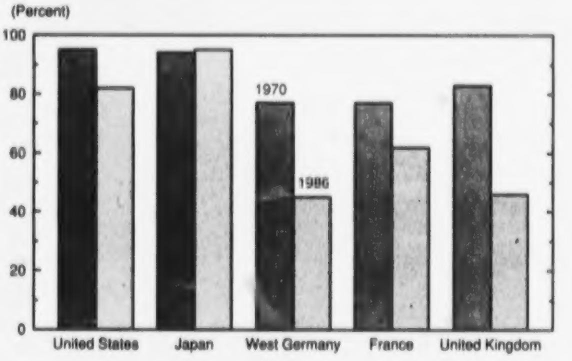
See appendix table 7-7.

Science & Engineering Indicators—1989

maintained market share of 93 percent to 95 percent throughout the 16-year period.

Summary. The U.S. home market has shown considerable growth during the 1980s and has attracted increasing amounts of the world's production of high-tech goods—including that of U.S. manufacturers. The data appear to support the notion that the United States is a highly attractive market for the world's producers of high-technology goods. U.S. producers of high-tech products still maintain a dominant position in their home market, but that position is being challenged by foreign manufacturers.

Figure 7-5.
Shares of home markets for high-tech products supplied by domestic producers, for major countries: 1970 and 1986



See appendix table 7-5.

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Foreign Markets for High-Technology Products

Historically, the United States has not been an economy oriented toward serving foreign markets. The sheer size of the U.S. economy provided the U.S. business community with large markets that supported its operations and generally encouraged its expansion.[11] Consequently, U.S. commerce looked to overseas markets mostly as an afterthought. Mounting trade deficits, however, are now inciting interest in expanding U.S. exports. This section examines U.S. technology sales in foreign markets and the role exports have played over the years.

The U.S. Experience. U.S. producers are important suppliers of high-tech products in the overseas market, but they have not been able to increase their market share to any significant degree.[12] A comparison of U.S. producers' share of the foreign market for high-technology products in 1970 and 1986 shows a gain of only 1 point, from 10 percent to 11 percent.[13] (See appendix table 7-8.)

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[11] See Council of Economic Advisers (1989), pp. 234-38.

[12] Foreign markets are calculated by subtracting total U.S. consumption of high-tech products from OECD production of high-tech products.

[13] The exchange rate between the U.S. dollar and a trade-weighted average for the currencies of the other major industrialized countries was fairly stable for these 2 years.

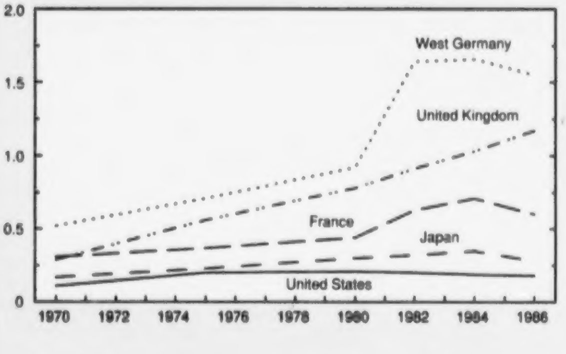
The United States consistently exported a larger share of its high-technology manufactures than non-high-technology manufactures. (See appendix table 7-9.) In 1978, about 18 percent of U.S. shipments of high-tech products were exported, compared with 4.5 percent of non-high-tech manufactured products. By 1986, the gap closed somewhat; high-tech exports still represented close to 18 percent of total high-tech shipments, but non-high-tech exports increased to almost 6 percent of total non-high-tech shipments.

Experience of Other Countries. By contrast, U.S. competitors have long emphasized exports of their high-technology products. (See appendix table 7-12.) In 1986, the United States exported 15 percent of its high-tech production, compared with 22 percent by Japan and substantially higher levels by the European countries.

Comparing each country's exports to its domestic shipments reveals the role foreign sales have played in each country's high-tech industries. During 1970-86, all of the other major industrialized countries exhibited comparatively greater tendencies to export than did the United States. (See figure 7-6 and appendix table 7-13.) West Germany's exports of high-technology products increased from half the size of its domestic sales in 1970 to 1.5 times its domestic shipments by 1986. Exports by the United Kingdom of high-tech products exceeded its domestic shipments of such products starting in 1984 and did so each year thereafter. France, with a home market comparable in size to that of West Germany, is less export-oriented than other European countries, but nevertheless had a much higher export/domestic shipment ratio than the United States.

Like that in the United States, Japan's strong home market for high-technology goods absorbed a larger share of its high-tech shipments than that accounted for by sales to foreign markets. Still, Japan's high-technology industry is considerably more export-oriented than is U.S. industry.

Figure 7-6.
Ratio of exports to domestic shipments for high-tech products, by country: 1970-86



See appendix table 7-13. *Science & Engineering Indicators—1989*

In 1986, the ratio of Japanese exports of high-tech products to domestic shipments was 0.3 to 1, up from 0.2 to 1 in 1970. In comparison, the U.S. export/domestic shipment ratio followed an irregular trend during the 16-year period examined. Even at its peak in 1980, it did not exceed 0.2 to 1.

U.S. Exports by Sector. While it is apparent that U.S. domestic sales of high-tech products far exceed its exports, that tends to obscure what continues to be a strong demand for U.S. high-technology products in foreign markets. In fact, the United States was the world's leading exporter of these until recently, when it was overtaken by Japan. (See appendix table 7-10.) In 1986, Japan supplied 24 percent of world exports of high-technology products; the United States' share was 22 percent.

Throughout the period examined (1978-86), exports of aircraft and related parts topped the list of U.S. high-tech exports, followed closely by exports of communication equipment and electronic components and of office and computing machines. (See appendix table 7-9.) Together, these three high-tech product groups account for a large and increasing share of all U.S. high-technology exports (68 percent in 1986, up from 60 percent in 1978), as well as of all manufacturing products (29 percent in 1986, 22 percent in 1978). Exports of computers and related equipment (office and computing machines) showed the most growth among the high-technology products, registering a threefold increase during the 1978-86 period.[14]

From 1976 through 1985, the United States maintained a consistent trade surplus for the identified high-tech product groups, and imported more than it exported of other manufactured products. (See appendix tables 7-14 and 7-15.) Since 1980, U.S. high-tech exports have continued to grow, but U.S. imports have grown faster. As a result, the U.S. high-technology trade surplus has declined substantially, dropping from about $27 billion in 1980 to under $4 billion in 1985. In 1986, the United States experienced its first trade deficit in the high-technology sector, with exports of $72.5 billion and imports of $75.1 billion. During 1987, U.S. trade in high-technology products (exports plus imports) jumped close to 14 percent over 1986, and returned to a slight surplus position as exports, once again, exceeded imports.

By contrast, the U.S. balance of trade for non-high-technology goods has been in deficit since 1975. During the 1980s, the U.S. annual trade deficit in this sector grew dramatically from $4.7 billion in 1980 to over $138.0 billion in 1987.

Summary. U.S. industries with high levels of R&D activities apparently maintain a comparative trade advantage—although this advantage is weakening. By inference, those U.S.-manufactured products that contain high levels of R&D inputs seem to be more competitive in foreign markets than do non-high-tech U.S. products. Increased competitiveness overseas provides additional revenues; this in turn provides resources for new private investment in R&D. The circular path of reinforcement of science and technology and U.S. competitiveness can be aided by success in foreign markets.

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[14] Companies in these three product groups also were particularly intensive in their R&D performance. In 1985, company-funded R&D expenditures in the industries associated with these products were about $19 billion, or almost 37 percent of the total industry-funded R&D effort in the United States. (See NSF, 1986.) Moreover, this measure probably understates the importance of these industries to the U.S. commercial R&D endeavor, since they also provide important markets for a variety of high-technology inputs and encourage R&D expenditures in various supplier industries.

INDIRECT CHANNELS FOR INTERNATIONAL DIFFUSION OF U.S. TECHNOLOGY

Profitable international diffusion of an innovation—whether through *exports, affiliate sales,* or *licensing* to a foreign producer—helps to finance and justify the innovator's R&D expenditures and thereby encourage new innovative activities. This section examines the trends of technology diffusion by U.S. firms through their various investments in foreign markets.

U.S. Direct Investment Abroad

Motivation for U.S. Foreign Investment. One way U.S. firms sell or transfer their products in foreign markets is by establishing production facilities in other countries. U.S. high-tech firms establish overseas operations in an effort to maximize revenues by exploiting all avenues to enhance the firm's ability to compete.

Firms establish overseas operations for many diverse reasons—to take advantage of lower operating costs, to avoid tariffs and/or other nontariff barriers in the host country, to better serve a market in which they have already achieved some success to name a few. The decision to invest overseas also may be related to the technology's age, with innovations initially exploited through exports, and production moving offshore as the product or process matures.[15]

Relative costs of production in the United States and in foreign countries are another factor. When production costs are substantially lower outside the United States, some level of production will, in time, be shifted overseas. These foreign affiliates will then tend to serve that country and region and may even replace U.S. production, especially for mature products whose manufacture incorporates readily available technical expertise and equipment. The movement toward such global manufacturing involves not only the manufacture of final products, but increasingly of parts and components that are then used to support final product manufacturing back in the United States.[16]

When a high-tech firm establishes a facility offshore, it expects to exploit some advantage it possesses, generally in the uniqueness of its product or its ability to service a market. New technologies and innovations generally are not transferred overseas until the later stages of the product cycle. By inference, these investments in foreign affiliates involve technologies that were introduced years before.

How much technical expertise or know-how is actually transferred when facilities are established overseas depends on the state of development of the prospective host country, with lesser developed countries having the potential for the greatest gain through both direct and indirect transfers of technology. Indirect technology transfers occur through the training of technicians and managers that result, and through the technical knowledge transferred to firms that support the facility and to customers trained in the use of the product. On the other hand, when developed countries are host to such foreign investment, they primarily get another competitor for their own production of similar high-tech products.

The data used in this section measure the book value of U.S. investors' equity in and outstanding debt with affiliated firms overseas.[17] While these data do not provide any information about the kind of investment, they do indicate both the level and location of U.S. commercial ties abroad.

Trends in U.S. Direct Investment. U.S. direct investment abroad in manufacturing industries exceeded $92 billion by 1981; this represents almost a threefold increase since 1970. (See appendix table 7-16.) After 1981, the uninterrupted growth in the U.S. foreign investment position stalled, thereafter following a more erratic path. As the United States slipped into recession after 1981, U.S. firms' investment position abroad declined. By the next year, it was down about 10 percent. This dip continued through 1984. By the end of that year, however, direct investment abroad began an upward trend that continued through 1987. The U.S. direct investment position in manufacturing industries abroad increased 21 percent from 1986 to 1987; this was about twice the rate of increase recorded in the prior 2 years.

This pattern was also mirrored by the two high-tech industries for which data are available—the chemicals and allied products and machinery manufacturing industries[18]—although the upward trend began a year earlier during 1983. The bulk of the increase between 1986 and 1987 is attributable to reinvestment of 1987 earnings, which were nearly double the level reported during 1986. These improved earnings were due to the effects of the dollar depreciation and enhanced operating profits, which in turn derived from strong demand and an improvement in operating efficiencies after some corporate restructuring.[19]

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[15] See Vernon (1966) and Hufbauer (1966) for more extensive discussion of the "product cycle."

[16] In addition, U.S. multinationals are, with increasing frequency, entering into agreements with individual foreign manufacturers to have them supply parts and components that were formerly manufactured in the United States.

[17] These data measure the book value of U.S. direct investors' equity in, and net outstanding loans to, their foreign affiliates. "Affiliates" are firms in which the reporting U.S. parent holds an interest of at least 10 percent of the voting securities, or the equivalent. See U.S. DOC, Bureau of Economic Analysis (1985); and U.S. DOC, Bureau of Economic Analysis (1987).

[18] Includes the nonelectrical machinery and electric and electronic equipment industry groups.

[19] Scholl and Lowe (1988).

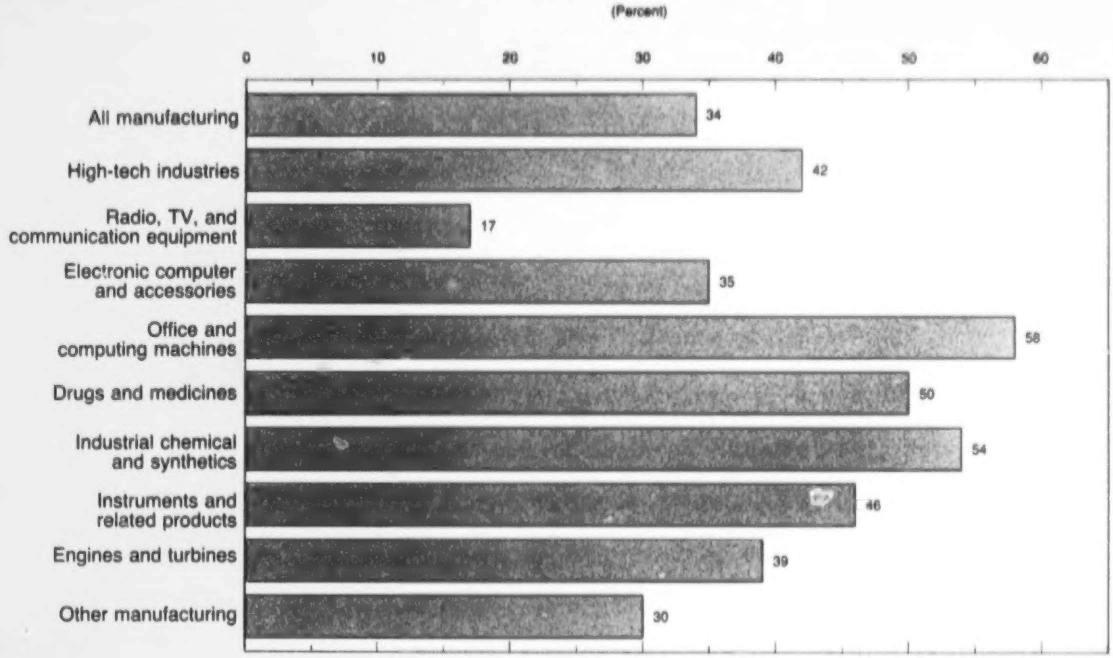
The geographical location of U.S. investment in overseas subsidiaries has changed substantially over the years, shifting away from Europe and toward the Asian-Pacific countries. (See appendix table 7-16.) In 1966, U.S. direct investment in Canada and the United Kingdom made up nearly 50 percent of the total U.S. direct investment position abroad in manufacturing; by 1987, this combined investment had declined to 35 percent. In 1966, West Germany and France were each host to three to four times as much U.S. direct investment as Japan for all manufacturing industries, and about twice as much as in the machinery and chemical industries. By 1987, however, the comparable U.S. direct investment position in Japan grew considerably, and in fact actually exceeded that in West Germany and France in the high-technology manufacturing industry of chemical products. Other Asian-Pacific countries also received larger amounts of U.S. direct investment between 1966 and 1987 as did Mexico and other lesser developed countries.

U.S. Direct Investment by High-Tech Multinationals. Establishing foreign affiliates provides U.S. firms with a means by which to break into a new market or improve their position in an existing market. Foreign affiliates also provide a mechanism to circumvent certain barriers erected to limit foreign competition. The data for 1986 suggest that high-tech manufacturing firms maintain a significantly higher portion of their assets in foreign affiliates than do other U.S. manufacturers. Assets of foreign affiliates for high-tech manufacturers accounted for nearly 42 percent of the parents' total assets, compared with 30 percent of total assets held abroad by non-high-tech manufacturers. (See figure 7-7 and appendix table 7-18.) U.S. parent firms operating in three high-tech fields—office and computing machines, drugs and medicines, and industrial chemicals—had assets in foreign affiliates representing over 50 percent of total assets.

The locations of the foreign affiliates set up by these high-technology firms suggest a bias associated with different products. U.S. multinationals' foreign investments in affiliated companies generally are heavily concentrated in Europe.[20] U.S. high-tech multinationals had 47 percent of their total assets in European foreign affiliates, compared with 42 percent for non-high-tech multinationals. (See figure 7-8 and appendix table 7-17.)

Affiliates established in Europe and Japan probably represent efforts by U.S. multinationals to expand sales in those markets. High-tech multinationals had 59 percent of

Figure 7-7.
Total foreign assets of U.S. corporations as a percentage of total assets: 1986



See appendix table 7-18.

Science & Engineering Indicators—1989

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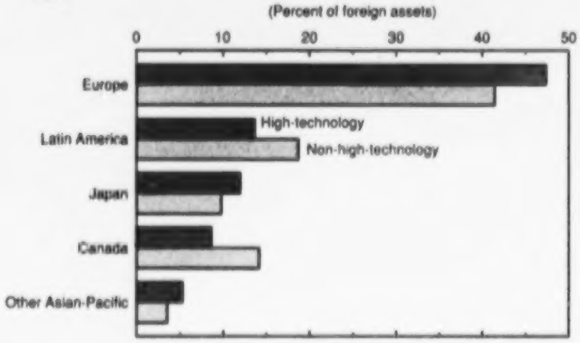
[20] Europe is defined as the 10 member countries of the European Community.

Figure 7-8.
Location of foreign affiliates of U.S. corporations: 1986



See appendix table 7-17. *Science & Engineering Indicators—1989*

their assets in foreign affiliates located in Europe and Japan (47 percent and 12 percent, respectively), while non-high-tech multinationals maintained 51 percent in Europe and Japan (41 percent and 10 percent, respectively). U.S. multinationals whose primary business involved computers (office and computing machines category) had close to 67 percent of their assets in Europe and Japan (52 percent and 15 percent, respectively), the highest for any high-technology field.

For the most part, foreign affiliate assets held by U.S. multinationals in the developing countries represent efforts to lower production costs and thereby increase competitiveness worldwide. Products manufactured in the developing countries are, for the most part, exported to developed countries, including the U.S. multinationals' home market. Many U.S. multinationals followed this path during the early 1980s when the appreciating dollar provided additional reason to move production facilities overseas. The experience did not always live up to expectations. Differences in culture, language, and business practices, as well as the distance from the U.S. headquarters, create additional costs that can erode much of the cost advantage that a firm expects to reap. With the dollar falling during 1987-88, there has even been some movement of production capability back to the United States, especially by firms that had not made the move offshore.

High-tech multinationals held 19 percent of their total assets in developing countries, compared with 22 percent for non-high-tech multinationals. Interestingly, U.S. multinationals whose primary activity involves the manufacture of computers had fewer assets tied up in developing countries than did U.S. manufacturers of other high-tech products. The rapidity with which technological changes occur in the computer field and the concomitant need for proximity to the innovative personnel may preclude offshore production except for the least sophisticated of computer products.

These data suggest that U.S. multinationals invest in foreign affiliates primarily to improve their market share in other developed countries. The suggestion is even stronger for U.S. multinationals in high-tech fields. Both the European Community and Japan represent large markets for high-technology goods; both protect these markets with trade barriers such as tariffs, "buy national" policies, and often unnecessary and discriminatory standards, testing, certifications, etc.[21] Foreign affiliates help U.S. firms circumvent the trade barriers that have impeded their competitiveness in the past. In general, the motivation for U.S. multinationals to establish foreign affiliates in lesser developed countries is to lower average production costs.

A recent U.S. International Trade Commission study appears to support these conclusions.[22] The commission found that:

- U.S. firms set up production facilities in Canada and Europe to facilitate sales in those markets.
- U.S. firms set up production facilities in Japan because they considered it a stable place to operate and because physical presence in Japan afforded firms better access to Japan's advanced technology.[23]
- In other East Asian countries, labor cost differentials and labor productivity were the incentives for U.S. firms' establishment of production facilities.

Patent Licenses, Royalties, and Technology Agreements

Although exporting and investing abroad are two very different strategies employed by U.S. companies to market their products in foreign countries, these strategies have an important element in common: any proprietary technology associated with the product being exported or manufactured by the foreign facility essentially remains controlled by the U.S. firm.[24]

Firms also may simply sell their rights to an invention, sell the right to market an invention, and/or provide technical information on an invention's production or use to another firm. The purchaser obtains a technological resource it may then use to its advantage—perhaps through production, modification, or marketing—and pays licensing fees and royalties to the original firm; these are frequently proportional to product sales.[25]

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[21] See Office of the United States Trade Representative (1987), pp. 95-109 and 171-93.

[22] See U.S. ITC (1988a), pp. 5-1 to 5-7.

[23] Ibid. Most of the responding U.S. companies with production facilities in Japan were themselves subsidiaries of Japanese companies. The ITC study suggests that responses may be different if more respondents selecting this reason were not owned by Japanese multinationals.

[24] Both these channels for product sales provide opportunities for leakage of such proprietary know-how. The sale of high-tech products involves the export of so-called "embodied technology." The technology incorporated in the product often can be pirated through reverse engineering, thus permitting competitors to imitate and perhaps even improve upon the product.

U.S. investment in overseas production facilities also inadvertently transfers technology. First, the innovative firm sets up production of its technology-embodying product in the market, creating a transfer of technology analogous to that accompanying high-technology product export. Second, there is a transfer of "disembodied technology"—in setting up production facilities, the investing firm brings a panoply of formal and informal know-how associated with the technology's use and production. Through exposure to production facilities, competitors and potential competitors again reap benefits from the innovator's R&D.

The inventing firm will often choose this marketing channel when it lacks the resources to exploit the technology fully (e.g., insufficient capital, raw materials, marketing expertise, etc.). Selling licenses to foreigners that permit the technology's reproduction, use, or resale typically take place when access to a market is made difficult because of tariffs, government restrictions, or lack of expertise about the market or customs that would facilitate the originating firm's entry. In return for the fee or royalty, the licensor sells not just information, but also partial control over the technology. The licensee gains knowledge or access to technology that would not otherwise be legally available.

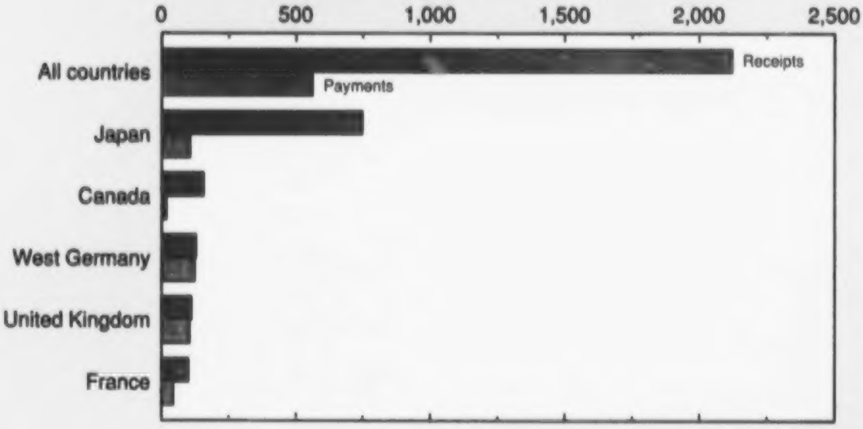
To some extent, firms' receipts and payments for patents and technical knowledge represent a pure indicator of technological prowess. These sales—particularly between unaffiliated firms where prices are set through some market-related bargaining process—reflect only the exchange of technology and its market value at that point in time. These receipts and payments thus may be viewed as an "output" indicator providing a measure of the production and exchange of knowledge.

The United States is a net exporter of its technology via this mechanism. Royalties and licensing fees received from foreigners have been, on average, four times that paid out to foreigners by U.S. firms for access to their technology. (See appendix table 7-19.) In real terms, U.S. sales of technology through this channel were more or less constant during the 1970s, but have shown considerable growth during the 1980s.[26] U.S. receipts from such technology sales totaled $2.1 billion in 1987 (1982 prices), up from $1.4 billion in 1980.

Japan is the largest consumer of U.S. technology sold in this manner. In 1987, Japan accounted for 41 percent of all such U.S. receipts, with Canada a distant second at 7 percent. Both these countries' payments for U.S. licenses were smaller in 1980—Japan accounted for 31 percent and Canada 5 percent that year. By contrast, purchases of U.S. technological know-how by other major industrialized countries—namely West Germany, the United Kingdom, and France—declined somewhat during the 1980s.

The United States has consistently maintained a trade surplus (i.e., receipts minus payments) in its sales of U.S. technology via this mechanism. (See figure 7-9.) In 1987, U.S. receipts were seven times its payments in licensing transactions entered into with Japan, eight times as large with Canada, and more than twice the payments to France. While the U.S. has maintained a surplus with West Germany and the United Kingdom, those surpluses have shrunk over the last couple of years and, as of 1987, were relatively small.

Figure 7-9.
U.S. receipts and payments of royalties and fees associated with unaffiliated foreign residents, by country: 1987
(Millions of dollars)



See appendix table 7-19.

Science & Engineeri[illegible]ndicators—1989

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[25] Licensing fees are charges for the use of a patent or industrial process; royalties are payments for the use of copyrights or trademarks.

[26] Since receipts from royalties and fees paid by foreigners represent an export of U.S. goods, an export deflator developed by the Department of Commerce was used to discount the inflation-added value to these data. Appendix table 7-20 contains deflators for general exports and imports.

U.S. payments to technology sellers in the United Kingdom are larger than might be expected given the size of the British R&D endeavor. In 1985, United Kingdom R&D expenditures were less than one-third those of Japan, and about two-thirds the level in West Germany;[27] nonetheless, the United Kingdom received almost 30 percent of U.S. technology payments that year. (See appendix table 7-19.)

The total flows of receipts and payments of royalties and license fees are generated from new agreements and those made in previous periods that are still in force. Consequently, these data do not permit an analysis of new U.S. technology flows resulting from new agreements. While data on receipts and payments from new technology agreements are not available from U.S. sources, there are some data developed by the Government of Japan that disaggregate data for receipts and payments by new and existing agreements. (See appendix tables 7-21 and 7-22.) Since Japan is the dominant customer for U.S. technology sold through this channel and a major force in high-tech fields, these data provide additional insight about the relatively high level of U.S. technology sold via technology agreements.

During the 1980s, the United States entered into, on average, over 800 new agreements per year with Japan involving the exchange of technological know-how. There were 2.5 new agreements calling for U.S. exports to Japan of technological know-how for every 1 that represented a U.S. import of Japanese technology. Interestingly, during the 1970s, the exchange of technological know-how between the United States and Japan was more equitable; the ratio of new agreements representing U.S. exports of technological know-how compared with U.S. imports of Japanese know-how was approximately 1.2 to 1.

Japan apparently continues to consider the United States a fertile field from which to harvest new advances in technology. The surplus the United States enjoys in its trade in technological know-how with Japan does not rely solely on technological advances developed in the past, but is also supported by current innovative activity in the United States. While such sales contribute positively to the balance sheets of U.S. firms and the U.S. economy in the short term there remains considerable controversy about the long-term consequences of these technology sales.

PROSPECTS FOR U.S. TECHNOLOGY IN THE GLOBAL MARKETPLACE

Policy Developments

The role government plays in a country's ability to compete in the global marketplace is a subject of debate that converts few but engages a great many. Nevertheless, governments do intervene in the marketplace for a variety of reasons—many times in response to its philosophy, occasionally for social concerns, frequently in response to pressure from interested parties. This section explores changes in U.S. Government policy that affect U.S. commerce and its ability to compete in the global marketplace.

The year 1988 saw both significant changes in U.S. trade laws and progress in bilateral negotiations intended to provide new opportunities for U.S. trade. On the other hand, the European Community is preparing to enhance its competitive position in 1992 by further removing trade barriers among member countries. There are fears among some U.S. and other non-European manufacturers that they could find themselves at a comparative disadvantage in their efforts to sell to the European market unless they establish production facilities within Europe. But probably the most important policy development in 1988 for U.S. firms involved in international commerce is what was commonly referred to as the Trade Bill.

With President Reagan's signing into law of the Omnibus Trade and Competitiveness Act of 1988 on August 23, 1988, the U.S. Government attempted to "level the playing field"—i.e., to increase opportunities for U.S. firms overseas and equalize the terms of economic competition within the United States.

Several provisions of the act bear heavily on U.S. trade, including trade in high-tech products. Briefly, the act:

- Mandates the President to seek lower tariffs and eliminate nontariff barriers through both multilateral and bilateral negotiations.
- Required the U.S. to join 50 countries in the Harmonized Tariff on January 1, 1989; this will facilitate U.S. exporters' ability to market their products.
- Clarifies the Foreign Corrupt Practices Act to identify permissible foreign payments when doing business overseas.
- Empowers the President to restrict acquisitions of U.S. firms by foreigners when deemed important to national security.
- Requires that export controls on sensitive products and services be continuously reevaluated so that only those items truly important to safeguarding national security remain controlled.
- Implements new requirements for reciprocity in intellectual property, government procurement opportunities, and telecommunications trade.
- Expands the laws governing intellectual property rights to include process patents, and makes the laws less burdensome for those seeking government protection from infringing imports.
- Strengthens "unfair trade" statutes (e.g., antidumping and countervailing duty laws).
- Creates the Competitiveness Policy Council consisting of government, business, labor, and academic leaders with the mandate to identify and analyze problems and recommend strategies for improving U.S. productivity and competitiveness.
- Renames the National Bureau of Standards as the National Institute of Standards and Technology to

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[27] See NSF (1987), p. 2.

reflect its broadened role. It is expected that the institute will become the lead Federal organization supporting industrial quality and competitiveness. The act directs the institute to involve itself in exchanges with foreign institutions to promote international exchanges of information on new technologies. The Advanced Technology Program is created under the institute's umbrella to function as a conduit to facilitate private sector access to the knowledge assembled by the institute and other Federal labs.

- Creates a 1-year National Advisory Commission on Superconductors consisting of members from government and the private sector to formulate a national strategy to ensure U.S. superconductor competitiveness.

The act's provisions go well beyond the areas summarized above. But potential gains for the U.S. economy are large in just two areas alone—the act's attention to export controls imposed on sensitive products and services, and to intellectual property rights.

A recent study conducted by the National Academy of Sciences assessed the impact of export controls on lost sales by U.S. firms, and suggested that these could exceed $9 billion dollars annually.[28] Most of the goods covered by export controls would be classified as high-technology products. While the act does not eliminate such controls, it does ease administrative burdens for firms involved in such trade, and it provides for ongoing removal of controlled products from the list of covered products as other countries make them available in the global marketplace. These changes will open markets previously closed to U.S. firms that trade in controlled products.

Another area of concern to U.S. high-tech firms addressed by the act is the need to strengthen intellectual property laws. A study by the U.S. International Trade Commission estimated that losses to U.S. firms as a result of violating U.S. intellectual property rights exceeded $11 billion dollars during 1986.[29] Again, a large percentage of the goods affected by these violations involve new products and processes in the high-technology area.

Almost 3 years in the making, the act is ambitious in its attempt to address so many areas of concern to U.S. business and labor communities. What impact it will ultimately have on U.S. competitiveness will be answered in the years to come.

Economic Factors

As a reference for the examination of U.S. competitiveness in high-technology fields, data on several important economic factors are presented to help explain potential shifts in technology flows. The factors selected—comparative exchange and inflation rates—are important factors, though they are not the only economic factors affecting U.S. international commerce. By tracking certain key economic factors, we may better understand the dynamics that influence future U.S. competitiveness.

As discussed earlier, consumers of high-technology products choose a particular supplier after carefully considering the product's ability to perform the required function, its quality, and its price. While high-tech products may tend to be less price sensitive[30] than other goods—especially those incorporating cutting-edge improvements or which are themselves state of the art—the bulk of products identified as high technology compete in a market composed of many competent sellers. Thus, sales of high-tech products will often turn on price. Two important elements that influence the price competitiveness of U.S. products are the *relative exchange rates* and *inflation rates* of the United States and of the countries that it competes against in the marketplace.

Increasingly, during 1980-85, U.S. firms were at a competitive disadvantage in the global marketplace due to a strong and strengthening dollar and an inflation rate higher than three of its major competitors—i.e., Japan, West Germany, and France. (See appendix tables 7-2 and 7-23.) During this period, the dollar appreciated close to 29 percent against the major industrialized countries.[31] The U.S. inflation rate was 3 times that in Japan and 1.5 times that in West Germany—these two countries alone accounted for 28 percent of global production of high-technology products. But after 1985, the prospect for improved price competitiveness for U.S. high-tech products stemming from changes in inflation and exchange rates predicts improved opportunities for U.S. high-technology products in the global marketplace.

In a DOC study analyzing the future price competitiveness of U.S. goods in world markets, several references to segments of the U.S. high-tech industry are mentioned.[32] Based on the level of U.S. exports of high-technology products in 1986 and the sources of competition for U.S. products in foreign markets, prospects for improved price competitiveness of U.S. high-tech products are strong both at home and in overseas markets. (See appendix table 7-25.) In the U.S. market, the estimated effect of currency and inflation changes projects an improved price-competitive position on some $32 billion dollars worth of high-tech products lost to foreign suppliers. Except for Canada, U.S. high-tech products should be more price competitive against the other major industrialized countries. Gains in the U.S. market at the expense of the lesser developed countries are predicted to be less favorable. According to this study, drugs and instrumentation products offer the greatest opportunities for increased U.S. high-tech product sales.[33]

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[28] See National Academy of Sciences (1987), pp. 122 and 266.

[29] See U.S. ITC (1988b), pp. 4-5 and 4-6.

[30] High-tech products often can be unique, customized, or otherwise state of the art; sales of such goods are influenced less by price.

[31] Exchange rate comparison of U.S. dollar with the 13-Developed Country Average. See appendix table 7-2 for list of countries.

[32] Lawson and Young (1988), pp. 16-21.

[33] Opportunities for increased sales of U.S. high-tech products in the home market were considered "favorable" if the combined effect of recent price and currency changes has been to cause prices of goods from major foreign suppliers to increase much more rapidly—or to decrease much more slowly—relative to the average price of all other goods sold in the United States, including U.S. domestic and other imports.

In overseas markets, the DOC study foresees opportunities for market expansion in high-technology fields that could involve close to $27 billion in new sales. The dollar's decline should lead to gains in trade in markets in Europe and Japan and—to a lesser extent—in the East Asian NICs. Once again, pharmaceuticals offer the greatest prospects for capturing further market share overseas; U.S. chemical products are also projected to be more price competitive.[34]

Other economic factors project mixed signals for the immediate future. Gains in U.S. labor productivity lag behind those made by our major competitors and U.S. labor costs remain high. The savings rate in the United States remains well below that of our nearest competitors; this contributes to a cost of capital higher than that of our competitors.[35] The burdens of comparatively higher interest rates and labor costs, and a lower savings pool kept low by very high consumption habits, will continue to be a drag on the positive forces that have entered the competitiveness equation.

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[34] In this DOC study, recent price and currency changes in markets outside of the United States are said to be "favorable" to U.S. exports if their combined effect has been to cause U.S. prices to drop much more rapidly—or to increase much more slowly—relative to the average price of goods from all other sources.

[35] See Hatsopoulos, Drugman, and Summers (1988), pp. 299-307.

REFERENCES

Boretsky, M. 1982. "The Threat to U.S. High Technology Industries: Economic and National Security Implications." Unpublished report. Washington, DC: U.S. Department of Commerce, International Trade Administration.

Council of Economic Advisers. 1989. *Economic Report of the President*. Washington, DC: Government Printing Office.

Davis, L.A. 1982. "Technology Intensity of U.S. Output and Trade." Staff report. Washington, DC: U.S. Department of Commerce, International Trade Administration.

Dornbusch, R., J. Porteba, and L. Summers. 1988. "Business, Economics, and the Oval Office: Advice to the New President and Other CEOs." *Harvard Business Review* no. 6 (November-December): 76-80.

Hatsopoulos, G., P. Drugman, and L. Summers. 1988. "U.S. Competitiveness: Beyond the Trade Deficit." *Science* 241 (15 July): 299-307.

Hufbauer, G.C. 1966. *Synthetic Materials and the Theory of International Trade*. London: G. Duckworth and Company.

Kelly, R.K. 1976. "Alternative Measures of Technology-Intensive Trade." *Staff Economic Report*. Washington, DC: U.S. Department of Commerce, Office of Economic Research.

Lawson, A., and K. Young. 1988. "Changing U.S. Competitive Price Position in World Markets." *1988 U.S. Industrial Outlook*. Washington, DC: U.S. Department of Commerce, International Trade Administration.

Milberg, W. 1988. "The Product Line Life Cycle Model of Intra-Industry Trade." *Eastern Economic Journal* XIV, no. 4 (October-December): 389-97.

National Academy of Sciences. 1987. *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition*. Washington, DC: National Academy Press.

National Science Foundation (NSF). 1987. *International Science and Technology*. Washington, DC: NSF.

____. 1986. *Research and Development in Industry*. Washington, DC: NSF.

Office of the United States Trade Representative. 1987. *Foreign Trade Barriers*. Washington, DC: Government Printing Office.

Scholl, R., and J. Lowe. 1988. "The International Investment Position of the United States in 1987." *Survey of Current Business* 68 (June): 80.

U.S. Department of Commerce (DOC), Bureau of Economic Analysis. 1987. "U.S. Direct Investment Abroad: Country and Industry Detail for Position and Balance of Payment Flows, 1986." *Survey of Current Business* 67, no. 8 (August).

____. 1985. "U.S. Direct Investment Abroad: Country and Industry Detail for Position and Balance of Payment Flows, 1984." *Survey of Current Business* 65, no. 8 (August).

U.S. DOC, International Trade Administration (ITA). *1988 U.S. Industrial Outlook*. Washington, DC: ITA.

U.S. International Trade Commission (ITC). 1988a. "Factors That Influence Plant Location Decisions." *The Use and Economic Impact of TSUS Items 806.3 and 807.00, Report to the Subcommittee on Trade, Committee on Ways and Means U.S. House of Representatives*. USITC Publication No. 2053. Washington, DC: ITC.

____. 1988b. "Foreign Protection of Intellectual Property Rights and the Effect on U.S. Industry and Trade." Report to the United States Trade Representative. USITC Publication No. 2065. Washington, DC: ITC.

____. 1988c. *Internal Combustion Engine Forklift Trucks from Japan*. USITC Publication No. 2082. Washington, DC: ITC.

Vernon, R. 1966. "International Investment and International Trade in the Product Cycle." *Quarterly Journal of Economics* 80 (May).

Chapter 8
Public Science Literacy and Attitudes Toward Science and Technology

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Public Science Literacy and Attitudes Toward Science and Technology

HIGHLIGHTS

- *The U.S. adult public has a very limited knowledge of physics and earth science.* Only 15 percent of American adults surveyed in 1988 could correctly answer all of seven simple questions posed on these topics. Three-quarters knew that light travels faster than sound, but only 43 percent knew that electrons are smaller than atoms, which is one of the most elementary facts of the atomic theory of matter. British respondents, who were asked the same questions at the same time, did a little more poorly on average. (See pp. 165-66.)
- *With regard to astronomy, there are also many misconceptions.* Twenty-one percent of Americans believe the sun goes around the earth, while another 7 percent do not know which goes around which. Only 45 percent know that the earth takes a year to go around the sun. British responses to these questions were correct even less often. A majority of Americans believes that the universe remains constant in size. (See pp. 166-67.)
- *The U.S. and British publics are very well aware of some basic health facts,* such as that sunlight causes skin cancer, and that stress and smoking contribute to heart disease. On the other hand, only about a quarter are aware that antibiotics cannot kill viruses. Many people in both countries are confused as to why they should do things like eat fiber and not eat food additives. Large numbers of Americans and Britons believe these actions help prevent heart disease. (See p. 167.)
- *Many Americans do not know or do not believe scientific accounts of early human history.* About 43 percent doubt that humans are descended from other animal species. Much smaller percentages in Britain, Japan, and the 12-country European Community reject the idea of human evolution. About 45 percent of Americans believe that early humans lived at the same time as dinosaurs. (See pp. 168-69.)
- *About 6 percent each of Americans and Britons say they act on their astrological forecasts.* Among young Americans, those aged 18 to 24, the level is 10 percent. Among those without a high school diploma, it is 11 percent. The same groups are also most likely to think that astrology is scientific. (See p. 170.)
- *The American public overwhelmingly believes that the world is better off because of science.* In both 1957 and 1988, 88 percent of respondents expressed this view. In both years, strong majorities believed the general proposition that science makes our lives healthier, easier, and more comfortable; and that science does not break down people's ideas of right and wrong. A parallel British survey asking some of the same questions received generally more negative assessments of the effects of science. (See pp. 170-71.)
- *However, in some respects, there is less public confidence in science in 1988 than in 1957.* For example, the number of Americans who believe that science can solve problems like crime and mental illness dropped from 47 percent to 23 percent. While only 23 percent believed in 1957 that science breaks down people's ideas of right and wrong, 33 percent said this in 1988. This drop in confidence occurred some time between 1957 and 1979. (See p. 171.)
- *Scientists generally are highly regarded by the public.* For many years, they have ranked second only to physicians on a list of professionals in which the American public has confidence. The scientific community has gained slightly in public confidence since the early 1970s, in comparison with some other institutions. (See pp. 172-73.)
- *The public believes that science and technology are good long-range investments.* About 80 percent believed—in 1985 and 1988—that the government should support scientific research even when it brings no immediate benefits. (See p. 174.)
- *However, the public gives higher priority to government funding in areas that have direct social application,* such as helping older people, improving education, reducing pollution, and improving health care. The British survey, addressing the situation in that country, found greater interest than in the United States in increasing government funding for scientific research. (See pp. 173-74.)
- *Most people consider the current level of government regulation of various aspects of science and technology to be adequate, if not excessive.* Substantial minorities, however, would like to see more regulation. Forty-two percent want more regulation of the use of chemical food additives, and 31 percent want more control over the construction of nuclear power plants. A majority is happy with the present level of regulation of basic scientific research. There was a decrease from 1985 to 1988 in the number that wanted to see more regulation of new pharmaceutical products, perhaps because of the AIDS problem. (See p. 174.)
- *A small majority supports research on animals if it produces information about human health problems.* In Britain, on the other hand, more people oppose than support animal research. Americans who oppose it tend to be female or

young. Support for animal research increases among the older age groups. (See p. 5.)

- ***Between 1985 and 1988, there were numerous changes in public opinion about science and technology.*** **Positive changes included a higher overall assessment of the benefits of science as opposed to its harmful effects, and more optimistic assessments of the effect of science on daily life. Also, there was a large decrease in the percentage who regard scientists as dangerous. On the other side, there was more desire for the regulation of S&T, and more negative attitudes were expressed about the effects of technology on unemployment, animal research, the space program, and nuclear power. (See pp. 170-75.)**

Science and technology (S&T) are undeniably of increasing importance to the life of the Nation. The other chapters of this report measure the various ways in which science and technology have been growing and changing, both as to levels of activity and as to outputs and products. This chapter is devoted to an assessment of how well the public understands, and how it regards, these developments. The National Science Board first sponsored the collection of data on the attitudes of the U.S. public toward science and technology in 1972. Since then, surveys of increasing scope and sophistication have been conducted for *Science & Engineering Indicators* approximately every 2 years. This chapter reports on the latest of these surveys, conducted in 1988.

The first part of this chapter examines the science literacy of the adult public. This is a new feature, reflecting the current interest in this subject shown by government and in the media. The second part of the chapter deals with public attitudes toward science and technology. Both the science literacy and the public attitudes data were collected in coordination with a parallel survey in Britain supported by the British government. As a result, an extensive comparison of U.S. and British science literacy and attitudes is presented here for the first time. This cooperation between countries follows a similar joint project between the United States and Japan, the results of which were reported in *Science & Engineering Indicators—1987*.

Another new feature of this chapter is the repetition of some survey questions first used in 1957 so that changes in attitudes since that time can be shown. In general, the chapter emphasizes the comparison of public attitudes measured in 1988 with those collected in earlier years using the same questions.

PUBLIC SCIENCE LITERACY

There is growing recognition in the industrialized world that public science literacy is an important component of long-term social and economic growth and of effective citizenship. In recent years, various studies in the United States and elsewhere have examined national science and mathematics education systems in an effort to improve them and thereby raise the level of public science literacy.[1]

Industrial economies will increasingly depend on advanced technologies, and new economic realities will demand an increasingly sophisticated workforce. This is illustrated by the pervasive impact of computers in service and manufacturing industries. The ability to use computers and similar technologies at work often depends on workers' level of scientific and technical literacy.

In addition, the growing impact of science and technology on our lives has brought an increasing number of S&T issues into the national agenda. Nuclear power, acid rain, and the "greenhouse effect," as well as medical advances and technological competitiveness, are increasingly subjects of media attention and political discussion in the United States and other industrialized nations. The issue of the safety of genetically engineered hormones in meat has triggered a trade dispute between the United States and the European Community. Similarly, trade disputes between the United States and Japan have arisen over computer chips, communications systems, and other high-tech products. The number of scientific and technical issues that demand public attention shows every sign of continuing to grow.

There is evidence that the proportion of citizens able to understand and follow these scientific and technical issues is low. Studies have found that relatively few Americans understand basic scientific terms or can make sense of arguments from experts on issues like nuclear power. Further, studies of recent high school graduates in the United States do not point to significant improvement from earlier generations.[2]

It would be valuable to have reliable measures of the level of public science literacy so that the scope of the problem could be assessed, trends measured, and comparison made with other industrialized countries. Techniques for making such measurements are still under development. Difficulties are complicated by the need to develop criteria that can be used internationally. This chapter reports on one of the first efforts to measure science literacy with the U.S. adult public and compare it with science literacy in another major industrialized nation, in this case Britain.[3]

For this purpose, surveys of the U.S. and British publics were performed simultaneously in June and July of 1988. The questionnaires were partly developed by mutual exchange of questions, so that responses received in the two countries could be compared.[4], [5] Several dimensions of science literacy derived from these responses are treated separately in the following discussion.[6] Work is in progress to develop further the criteria for scientific and technological literacy and to extend the comparison to other countries.[7]

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[1] See chapters 1 and 2.

[2] The source for the above is Miller (1989b). The most recent major study of the problem of public science literacy is AAAS (1989).

[3] This chapter speaks of Britain rather than the United Kingdom because the data discussed were collected in England, Scotland, and Wales, but not in Northern Ireland.

Acquisition of Information About Science and Technology

The U.S. public is strongly convinced of the need to be informed about science. Eighty-four percent disagreed with the idea that "It is not important for me to know about science in my daily life."[8] The public also believes that knowledge of science is possible: 72 percent agree that "If scientific knowledge is explained clearly, most people will be able to understand it."[9] Scientific knowledge thus is considered both desirable and attainable. This section considers what the public is actually doing to acquire it. In general, the public claims to have a surprisingly high amount of access to various sources of information about science and technology, and some responses may in fact be exaggerated.

Naturally, formal education is the way in which many persons acquire a certain level of scientific knowledge. Thirty percent of the U.S. respondents said they had taken at least one college-level course in biology, chemistry, or physics.[10] Most of these people, of course, did not become professional scientists or engineers, but many of them presumably retained some appreciation of science in later life, whatever careers they pursued.

Those who never studied science academically—and even those who once did but are not now actively involved in science—must depend on various public information sources to develop and update their scientific knowledge. For example, *museums* represent one important effort by science professionals to impart science information to the public. Of the 1988 sample, 26 percent reported that they had attended an S&T museum at least once in the past year, and 10 percent said they had done so more than once. In addition, 30 percent said they had gone at least once to a natural history museum, which is a very similar facility,[11] and 51 percent said they had gone to a zoo or aquarium. (By comparison, 33 percent reported that they had visited an art museum, and 68 percent reported visiting a public library.) Virtually identical responses were given in 1985. Attendance at S&T museums is highest in the 35- to 44-year-old age group; 34 percent of those in this age bracket have visited in the past year, while only 11 percent of those over 65 have. Attendance is also highest in the college-graduate group, where 50 percent went to an S&T museum in the past year, as opposed to 11 percent of those who had not finished high school.

Magazines and television are other media that help to convey science and technology information to the broad public. Television seems to be particularly effective, at least in terms of the number of people reached. In 1988, 84 percent of American respondents reported that they "regularly" or "occasionally" watch the program "Nova" or the National Geographic specials. This is up from 59 percent in 1979, 70 percent in 1983, and 71 percent in 1985.[12] When asked to list the magazines they read regularly or occasionally, 15 percent of American respondents named at least one S&T-related magazine.[13] The following discussion deals with the levels of knowledge about science and technology that the public has actually achieved from all these sources.

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[4] The U.S. survey was performed in June and July 1988 with a representative sample of 2,041 adults aged 18 and over. Surveying was done by telephone at the Public Opinion Laboratory, Northern Illinois University. The response rate was 79 percent. With a sample of this size, results are uncertain by ± 3 percent or less at the 95-percent confidence level. With subsamples, the uncertainty will be greater. For simplicity, this chapter does not discuss the statistical significance of various differences in the data, but points out only differences regarded as significant. U.S. data discussed in this chapter, unless otherwise identified, are from Miller (forthcoming, 1989a). See also Miller (in press, 1990).

[5] The national survey of public understanding of science in Britain was performed in June and July 1988 by personal interviewing of 2,009 respondents representing England, Wales, and Scotland south of the Caledonian Canal. It was a joint project of the University of Oxford Department for External Studies and Social and Community Planning Research, funded by the Economic and Social Research Council. The British questionnaire was devised by John Durant, Geoffrey Evans, Patricia Prescott-Clarke, and Geoffrey Thomas, with advice and assistance from Donald Buzzelli, Barry Hedges, Roger Jowell, and Jon Miller. While the American data file has been reweighted to correct for any biases in the sample with respect to age, gender, race, or level of education, this has not been done with the British data. Unweighted samples tend to contain excessive numbers of educated respondents, so that slightly higher levels of science literacy are found in the British data than are justified. The British survey also offered "don't know" to the respondents as a possible reply to many questions, while the U.S. survey did not. In some cases, this may affect the interpretation of the results.

[6] No overall measure of national science literacy is developed in this chapter. However, a recent study using the present data found that 5.6 percent of the U.S. public can be considered scientifically literate. For the British public, also on the basis of these data, the corresponding figure is 7.1 percent. See Miller (1989b).

[7] This chapter deals with scientific literacy and has little to say about technological literacy. The National Science Foundation recognizes the importance of technological literacy, and efforts are planned to develop measures of it. However, at this stage, techniques for measuring science literacy are just beginning to be developed; even less is known about technological literacy. In any case, knowledge of science will certainly be a significant part of any measure of technological literacy.

[8] Another 14 percent agreed and 1 percent didn't answer. In Britain, not as many felt that knowledge of science is important. Only 57 percent disagreed with the statement, while 34 percent agreed, 8 percent neither agreed nor disagreed, and 1 percent gave no answer.

[9] Another 27 percent disagreed and 1 percent did not reply. In Britain, 73 percent agreed, 20 percent disagreed, 6 percent said "neither," and 1 percent did not reply. This is slightly more favorable to the possibility of public science education than is the American reply.

[10] Since the sample is reweighted to match the educational distribution of the whole public—along with other characteristics—this is probably a good representation of the extent of college-level science study among the entire U.S. adult population. For more detailed information on science and engineering education in the United States, see chapters 1 and 2.

[11] Forty-one percent reported attending either a science and technology museum or a natural history museum at least once in the past year.

[12] See Miller, Prewitt, and Pearson (1980); Miller (1983); and Miller (1985). In Britain, 84 percent reported watching one of the two most popular science-related television shows regularly or occasionally in 1988.

[13] In 1985, 16 percent gave that answer. Twelve percent of British respondents in 1988 stated that they read at least one magazine about "what is going on in science and technology."

Knowledge of Scientific Terms and Scientific Method

Scientific Terms. In their everyday reading, radio listening, or TV watching, people encounter news items that use more or less technical terms having to do with science and technology. Thus, an important component of being scientifically or technologically literate is the ability to understand a minimum number of technical terms when they are encountered. People often are able to understand these terms because of their formal education or from informal discussion or reading done later in life.

Previous studies have found that many people will say they know various technical terms when they really do not. Typically, less than half of those who say they have a clear understanding of a term can give a satisfactory definition of it if asked.[14] For example, 27 percent of American respondents claimed in 1985 that they had a clear idea of what a molecule is, though only 10 percent could give a satisfactory definition, even by generous standards. Similarly, only 8 percent could say how a telephone works, though 18 percent had claimed to understand its operation clearly. Thus, it is necessary to ask more specific questions in order to learn the actual level of public knowledge.

In 1988, American and British respondents were asked to give definitions for a set of terms. (See text table 8-1 and appendix table 8-1.)[15] Both American and British respondents were more familiar with computer software than with DNA.[16] In the case of DNA, more Americans than Britons appear to know what it is. On the other hand, very few Americans could give a definition of radiation that had some scientific content.[17] A larger number—a quarter of the U.S. sample—were able to give a less technical account of radiation, usually in terms of its effects or uses.[18] (See appendix table 8-1.)

Scientific Method. Another important aspect of being scientifically literate is having some knowledge of the methods and styles of thinking that characterize science. Advertising and the entertainment and news media often contain claims that some result has been established scientifically. The public should understand the habits of mind and procedures of science well enough to know what this claim means—and, perhaps, even to decide when it is likely to be true. In addition, scientific thinking is a thinking style that individuals often find valuable in their personal lives.

The question of what the public knows about the thinking or methods of science is a large one, but some information about it exists. (See text table 8-1.) Approximately 20 percent of the U.S. and British publics could explain what scientific study is. Three types of answers were regarded as correct. The first type had to do with the formulation and testing of hypotheses, leading to our best current understanding of nature. The second type had to do with performing experiments. The third type had to do with weighing all the evidence with an open mind.[19] More Britons than Americans gave correct answers. The first two answers were given in nearly equal numbers in both countries, but more Britons than Americans gave the third correct answer. (See appendix table 8-2.)

Text table 8-1. U.S. and British publics' knowledge of scientific terms and scientific method: 1988

	Percent answering correctly	
	U.S.	Britain
Terms		
Computer software	27	26
DNA	22	13
Radiation		
Scientific understanding	6	NA
Knows effects	25	NA
Scientific method	17	23
N =	2,041	2,009

NA = Not asked.

See appendix tables 8-1 and 8-2.

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Knowledge of Scientific Conclusions

A large part of being scientifically literate is knowing some of the conclusions that science has reached. Scientific research constantly produces new information of both theoretical and practical interest. The scientific community ought to be concerned about how much of this information has reached the public, both to expand people's intellectual horizons and to increase their ability to function in a technological society.

Physics and Earth Science. Public knowledge in this area was measured with seven questions, ranging from the very simple—e.g., whether hot air rises—to the more technical—e.g., how a laser works. (See text table 8-2.) There is a correspondingly wide variation in the numbers answering different questions correctly. While nearly everyone knew that hot air rises, only a minority knew that electrons are smaller than atoms or that lasers do not focus sound waves. The question about electrons is significant because it has to do with an elementary feature of the atomic theory

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[14] See NSB (1987), pp. 143f.

[15] These results are based on coding of the open-ended survey questions at the Public Opinion Laboratory, Northern Illinois University, and at Social and Community Planning Research, London, England. Tests were made of intercoder reliability and of consistency of the categories into which responses were coded.

[16] In a 1987 survey, Japanese respondents also found computer software more familiar than DNA. See NSB (1987), appendix table 8-4.

[17] Acceptable answers referred to "energy" or "waves," for example.

[18] Answers in this group might refer to "bombs," "the sun," "can kill you," "cancer," "fallout," "power plants," or to medical uses.

[19] A fourth group of respondents answered in terms of looking at things carefully. The remaining responses were unclassifiable. (See appendix table 8-2.) Responses for the U.S. sample were coded at the Public Opinion Laboratory, Northern Illinois University, with tests of intercoder reliability.

Text table 8-2. U.S. and British publics' knowledge of facts of physics and earth science: 1988

	Percent answering correctly	
	U.S.	Britain
"Hot air rises."	97	97
"The oxygen we breathe comes from plants."	81	60
"The center of the earth is very hot."	80	86
"The continents on which we live have been moving their location for millions of years and will continue to move in the future."[1]	80	71
"Which travels faster, light or sound?"	76	75
"Electrons are smaller than atoms."	43	31
"Lasers work by focusing sound waves."	36	42
Correct responses to all seven questions	15	12
N =	2,041	2,009

[1] British wording: "The continents are moving slowly about on the surface of the earth."

See appendix table 8-3.

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Text table 8-3. U.S., British, and European Community publics' knowledge of facts regarding astronomy

	Percent answering correctly		
	U.S. (1988)	Britain (1988)	EC (1989)
"In the entire universe, there are thousands of planets like our own on which life could have developed."	67	NA	NA
"The universe began with a huge explosion."	54	64	NA
"Does the earth go around the sun, or does the sun go around the earth?"	73	63	83
"How long does it take for the earth to go around the sun?"[1]	45	34	63
N =	2,041	2,009	11,678

NA = Not asked.

[1] Question was asked only of those who said earth goes around sun. Percentages are based on total sample.

See appendix table 8-4.

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of matter. Those who do not know the relative sizes of electrons and atoms are unlikely to have much comprehension of the structure of matter.

It is often more useful to look at the numbers who answered a group of questions correctly rather than look at individual questions. Individual questions can be answered correctly by guessing,[20] but it is not likely that someone can guess all the correct answers to a set of questions. Only 15 percent of American respondents were able to answer all the listed questions correctly. (See text table 8-2.)

British respondents, who were asked the same set of questions, did a little worse. While they scored about the same as Americans on several questions, they did relatively poorly on the questions about oxygen coming from plants and electrons being smaller than atoms; overall, only 12 percent answered all the questions correctly.[21]

Astronomy. Some disappointing results were also obtained regarding public knowledge about astronomy. (See text table 8-3.) While most people knew that the earth moves around the sun, 21 percent of American respondents thought the sun moved around the earth and 7 percent had no answer. (See appendix table 8-4.) Even more British respondents answered incorrectly. In both countries, about 19 percent of respondents knew that the earth goes around the sun, but thought that this motion takes one day or one month; another 8 percent to 10 percent knew the earth goes around the sun, but did not know how long it takes.

The same two questions were asked in a 1989 survey of the 12 countries of the European Community.[22] In the European Community as a whole, the percentage that knew that the earth goes around the sun was higher than in the U.S. and British surveys. Only 11 percent thought the sun goes around the earth. (See text table 8-3 and appendix table 8-4.)

The question about whether the universe began with a huge explosion (the "Big Bang") was answered correctly by a majority in both the United States and Britain. (See text table 8-3.) The U.S. response was characterized by a large percentage saying that was "definitely true," while another large percentage had no answer. (See appendix table 8-4.)

A related survey in 1986 studied the cosmological beliefs of Americans more deeply.[23] Fifty-five percent understood that the sun is a star like millions of others; 37 percent said that the sun will eventually burn out, thus showing an understanding of the impermanent nature of stars. The large numbers who believe in unidentified flying objects from other civilizations suggest a failure to understand the cosmic scale of distances and the consequent time it would take to travel from another star system to ours.[24]

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[20] Thus, the percentage of the public that actually knows some item of scientific information will be lower than reported here in many cases.

[21] Many of the items on text table 8-2 and later tables were developed by the Oxford University/Social and Community Planning Research team as part of the "Oxford Scientific Knowledge Scale."

[22] Interviewing was done in March and April 1989 by survey institutes in the individual countries, with coordination by the Faits et Opinions organization in Paris. Sample sizes were about 1,000 in each country—except for the United Kingdom (1,276) and Luxembourg (303)—for a total sample size of 11,678. To estimate the average for the entire European Community, responses from the individual countries were weighted according to national population counts of persons 15 years of age or older. See CEC (1989).

[23] Lightman and Miller (1989).

An understanding of the Big Bang theory would lead to the conclusion that the universe is getting bigger, but only 24 percent of American adults gave that response.[25] About 59 percent said the universe is remaining constant in size. About 19 percent stated, in response to another question, that they would be troubled to learn that the universe is expanding.

The most important characteristic of respondents in predicting their cosmological understanding was education. Other significant characteristics, in order of importance, were:

- Gender (men tended to have more understanding),
- Age (the 30- to 49-year-old age group had more cosmological understanding than younger or older groups), and
- Church membership (nonmembers had more understanding).[26]

Probability. An important dimension of science literacy is mathematical literacy, the ability to comprehend magnitudes and make simple estimations. One aspect of mathematical facility is comprehending statements about probability. The U.S. and British publics did relatively well in this area. (See text table 8-4.) The question asked for the meaning of the statement that a couple has a "one in four chance" of having a child who will inherit a certain illness. Respondents were offered four possible interpretations of that statement, of which only one was correct.

Most respondents were able to recognize and reject the wrong interpretations and endorse the right one. (See text table 8-4.) Americans did better than the British in rejecting the wrong responses, but they also rejected the right response more frequently—23 percent rejected option c. (See appendix table 8-5.) As a result, more Britons than Americans got all four questions right, though more Americans got three right.

Health. Some items of scientific knowledge are not only of intellectual interest, but can also affect the way people behave. This is especially true for information about health. When American and British respondents were asked a set of health questions, their responses were very similar. (See text table 8-5.) There was a very high level of recognition that sunlight can cause skin cancer and that cigarette smoking causes lung cancer. A majority knew that radioactive milk cannot be made safe by boiling it.[27] However, only a small minority knew that antibiotics cannot kill viruses. This lack of information could be important to someone who is being treated for influenza, or to someone who expects a cancer cure in the near future.

Text table 8-4. U.S. and British publics' understanding of probability: 1988

	Percent answering correctly	
	U.S.	Britain
"Now, think about this situation. A doctor tells a couple that their genetic makeup means that they've got a one in four chance of having a child with an inherited illness."		
a. "Does this mean that if they have only three children, none will have the illness?" ...	87	84
b. "Does this mean that if their first child has the illness, the next three will not?"	86	80
c. "Does this mean that each of the couple's children has the same risk of suffering from the illness?"	72	82
d. "Does this mean that if their first three children are healthy, the fourth will have the illness?"	84	80
Correct responses to all four questions	57	66
N =	2,041	2,009

See appendix table 8-5.

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American and British respondents were also asked whether certain things contribute to heart disease. (See text table 8-5.) Almost all recognized that stress, smoking, not exercising, and eating animal fat do contribute. However, there was confusion about four other possible causes: not eating fresh fruit, lack of vitamins, not eating much fiber, and eating food with additives. In the first three cases, roughly as many people thought they caused heart disease as thought they did not. (See appendix table 8-6.) There was especially strong feeling that food additives can contribute to heart disease. It is possible that the public has absorbed a set of rules about good health habits (e.g., eat vitamins, don't eat fat) without knowing exactly which sicknesses these rules are intended to prevent.

Only 7 percent of American respondents, and 9 percent of the British, knew exactly which items do and do not cause heart disease. Responses from the two countries were very similar, except that there may be less concern in Britain about the effect of eating animal fat.[28]

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[24] In 1985, 43 percent of American respondents said that "It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations." See NSB (1987), p. 154. In 1988, a question that was similar but encouraged more "don't know" responses received 25 percent affirmative answers and 32 percent "don't know."

[25] Lightman and Miller (1989).

[26] These effects are calculated independently, so that any difference in education between the genders, for example, is corrected for.

[27] According to news stories, this was a practical issue for some Soviet citizens immediately after the Chernobyl accident.

[28] U.S. and British respondents were also asked which is the most serious cause of heart disease in their country today. The three most frequently mentioned items in the U.S. were smoking (38 percent), eating animal fat (25 percent), and stress (18 percent). In Britain, this order was somewhat reversed, as respondents reported smoking (41 percent), stress (27 percent), and eating animal fat (20 percent).

Text table 8-5. U.S. and British publics' knowledge about health: 1988

	Percent answering correctly	
	U.S.	Britain
"Sunlight can cause skin cancer."	97	94
"Cigarette smoking causes lung cancer."	96	NA
"Radioactive milk can be made safe by boiling it."	64	65
"Antibiotics kill viruses as well as bacteria."	25	28
Items contributing to heart disease		
Stress	96	95
Smoking	95	93
Not getting much exercise	95	91
Eating a lot of animal fat	94	87
Eating very little fresh fruit	44	47
Lack of vitamins	43	39
Eating very little fiber	41	45
Eating food with a lot of additives	25	29
Correct response on all eight items	7	9
N =	2,041	2,009

NA = Not asked.

See appendix table 8-6.

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Human Origins. Quite a different sort of scientific information has to do with the origins of the human species. This issue is not only connected with scientific literacy, but also with antiscientific beliefs, which are discussed in the next section of this chapter. Nearly half of Americans believe that the human species is descended from earlier animals, while the percentage of British who believe this is much higher.[29] (See text table 8-6.) Nearly as many Americans reject human evolution (43 percent) as accept it. (See appendix table 8-7.) In Britain, as well as in Japan, there is no group of comparable size that opposes the idea of human evolution.[30]

The same question was asked in all 12 countries of the European Community in 1989. (See text table 8-6 and appendix table 8-7.) For the Community as a whole, there was a higher percentage answering correctly and a lower percentage answering incorrectly (only 24 percent) than in the United States. No European Community country had as large a minority opposed to human evolution as the United States has. According to preliminary data, the highest levels of rejection of evolution in the European Community were in The Netherlands (35 percent) and in Ireland (32 percent).

Text table 8-6. Beliefs of U.S., British, and European Community publics regarding human origins

	Percent answering correctly		
	U.S. (1988)	Britain (1988)	EC (1989)
"Human beings as we know them today developed from earlier species of animals."[1]	46	79	62
"The earliest humans lived at the same time as dinosaurs."	37	46	47
N =	2,041	2,009	11,678

NA = Not asked.

[1] British response includes both "definitely true" and "probably true."

See appendix table 8-7.

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American and British respondents were also asked whether early humans lived at the same time as the dinosaurs. (See text table 8-6.) More Americans gave the incorrect answer than the correct one to this question. (See appendix table 8-7.) This may be due to the frequent depiction of humans and dinosaurs together in popular comics and films, like the Flintstones.

Interestingly, 48 percent of those Americans who believed in human evolution mistakenly believed that humans lived at the same time as dinosaurs. About as many (44 percent) of those who did *not* believe in evolution similarly believed humans and dinosaurs shared the earth for a time. Many people do not seem to recognize the long periods of time and the relatively late appearance of humans that the theory of evolution involves. This is true equally of those who accept evolution and of those who do not. In all, only 18 percent of American respondents both believed in human evolution and knew that humans and dinosaurs did not coexist.

More British than American respondents knew that humans did not live at the same time as dinosaurs. (See text table 8-6.) In the case of the British, 33 percent of those who believed in human evolution believed that humans lived at the time of the dinosaurs, while 30 percent of those who did not believe in evolution believed that humans and dinosaurs coexisted. Again, there is little connection between the responses to the two questions. About 38 percent of the British believed that human evolution is "definitely true" or "probably true" and also knew that humans did not live in the time of the dinosaurs.

In the United States, human evolution is accepted more often:

- By males than by females—52 percent versus 40 percent,
- By younger people (those aged 18 to 24) than by those 65 and older—54 percent versus 37 percent, and

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[29] The British question allowed both "definitely true" and "probably true" as answers; the U.S. question did not. This may have caused a small increase in the relative numbers of Britons giving a positive answer, but there is still not nearly the same percentage of Britons as Americans giving a negative answer to the evolution question. (See appendix table 8-7.)

[30] For Japanese attitudes on this subject, see NSB (1987), pp. 153-55.

- By the more educated (college graduates) than by the less educated (those who did not finish high school)—63 percent versus 41 percent.

Scientific and Other World Pictures

Characteristics of Those Who Accept/Reject Scientific Conclusions. A recent analysis of the present set of U.S. and British data looked for the characteristics of those who accept or reject scientific conclusions in the areas of cosmology and evolutionary theory.[31] Reviewing the data discussed above, the study found that more Britons than Americans accept the Big Bang theory of the origin of the universe—64 percent versus 54 percent. (See text table 8-3.) It also found a very large difference in the number of Britons and Americans who accept human evolution—79 percent versus 46 percent. (See text table 8-6.)

The responses to these two questions were analyzed in terms of the responses to two others: (1) whether humans existed at the same time as dinosaurs (see text table 8-6), and (2) whether we depend too much on science and not enough on faith (see text table 8-10).

In both countries, a respondent's acceptance of human evolution is strongly associated with his or her acceptance of the Big Bang. Those who believed that we should depend more on faith were especially likely to reject human evolution; they were somewhat less likely to reject the Big Bang. The connection between reliance on faith and rejection of human evolution was particularly strong in the United States.

Further analysis found that the British responses to the Big Bang question could be explained entirely in terms of the respondents' levels of scientific knowledge—i.e., no effect was due to respondent education or religious belief. In the case of human evolution, however, both scientific knowledge and religious belief emerged as significant explanatory variables. Comparable data are not available for the United States.[32]

Limits of Scientific Method. While the U.S. public has considerable respect for science, it clearly has other interests. Many people feel that science is a limited field of study and that many important areas of life cannot be understood in scientific terms. For example, a majority of Americans believes that scientists will never be able to understand the workings of the human mind as well as they understand the physical world, and a large majority believes that there are good ways of treating sickness that medical science does not recognize.[33]

The general question of what things cannot be studied scientifically was asked of the U.S. public in 1957 and 1988. (See text table 8-7.) In 1988, a majority believed that science can delve into anything. This is more than the number who gave that answer in 1957, but in that year there was an especially large number who had no opinion.

Text table 8-7. Public belief about the limits of the scientific approach: 1957 and 1988

	1988
	(Percent)
Science cannot study	
Some things, but cannot say what	6
Religion, God, faith	12
Human behavior, thought	6
Nature: remote parts, origin; disease	4
Values, humanities, literature	2
Spiritual, unknown	1
Other	1
Science can study anything	59
Don't know/no answer	8
	N = 2,041

	1957
Science cannot study	
Some things, but don't know what they are	13
Religion, faith, the Bible	5
Human behavior, thought	4
Spiritual realms and beings	2
Aesthetic things, art, beauty	1
Humanistic areas, history, philosophy	1
Other miscellaneous areas	3
Science can study anything	47
Don't know/no answer	26
	N = 1,919

1988: "Are there any things that cannot be studied scientifically?"
IF YES: "What are some things that cannot be studied scientifically?"

1957: "Are there any things that can't be studied scientifically?"

Note: Multiple answers were accepted in 1957.

SOURCES: Survey Research Center (1958); Miller (1989a).

Science & Engineering Indicators—1989

Of the respondents who thought that some things cannot be studied scientifically, few in either year could name anything specifically. The answers that were given tended to center on the spiritual or religious. Other answers broadly referred to human thought and values. For some respondents, human origins evidently fall into this human and religious area that is outside the scope of science.

Nonscientific Beliefs. Large portions of the public hold beliefs that are inconsistent with the scientific world picture. For example, 44 percent believed in 1985 that rocket launchings and other space activities have caused changes in our weather.[34] This is inconsistent with scientific knowledge about the causes of weather changes or the effect something as small as a rocket could have on the atmosphere. In 1988, 37 percent of Americans believed that some numbers are especially lucky for some people.[35]

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[31] See Evans and Durant (1989); also Durant, Evans, and Thomas (1989).

[32] However, the 1985 survey of U.S. adult public attitudes toward science and technology (reported in NSB, 1987, chapter 8) found—among other things—that 14 percent of church members "strongly disagreed" with human evolution, while only 3 percent of nonmembers did so.

[33] See NSB (1987), p. 156.

[34] See NSB (1987), p. 154.

[35] In addition, 58 percent disagreed and 5 percent had no opinion.

Again, number mysticism in its various forms is incompatible with the kind of causality recognized by science.

Astrology offers an especially interesting alternative to the scientific world picture. Influences of a kind that science does not recognize, coming from various astral bodies, are supposed to affect the characters of individuals and what happens to them. Knowledge of these influences is supposed to help in predicting the future, somewhat in the way the laws of a given science are used in making predictions. Technical language, charts, and calculations are employed that have some resemblance to those employed in the sciences, especially astronomy.

Perhaps because of these similarities, a significant portion of the public has astrology somewhat confused with science. (See text table 8-8.) While not many consider astrology "very scientific," a large minority regards it as "sort of scientific"; 37 percent give one answer or the other. On the other hand, the number who consider astrology "not at all scientific" has increased since 1979. The scientific status of astrology is accepted more often by women than by men, by those in the youngest age group (18 to 24), and by those with the least education. (See appendix table 8-8.)

While 17 percent of Americans say they read their personal astrology reports "every day" or "quite often," the number who say they act on these reports is much smaller, in the range of 5 percent to 8 percent. (See text table 8-8.) However, in view of the social stigma sometimes attached to such practices as astrology, the actual frequency may be higher than reported here. The same variation with gender, age, and education is seen as with the question on whether astrology is scientific. (See appendix table 8-8.)

Text table 8-8. Public attitudes toward astrology

	1979	1985	1988
	— Percent —		
"Would you say that astrology is very scientific, sort of scientific, or not at all scientific?"			
Very	8	8	6
Sort of	34	31	31
Not at all	50	57	60
Don't know/no answer	9	4	3
"In your daily life, do you sometimes decide to do or not to do something because your astrological signs for the day are favorable or unfavorable?"			
Yes	5	8	6
No	95	88	94
Don't know/no answer	NA	4	0
N =	1,635	2,005	2,041

NA = Not asked.

See appendix table 8-8.

Science & Engineering Indicators—1989

Those respondents who said in 1988 that they act on their astrological forecasts were further asked what those actions were. Fewer than half gave an answer. Of the answers given, many had to do with being careful about traveling or going out. Not spending money was the subject mentioned next in frequency.

In some respects, the British public shows more support for astrology than does the U.S. public. While only 6 percent of Americans consider astrology very scientific, at least 12 percent of Britons do.[36] The readership of personal astrology reports is greater in Britain than in the United States.[37] The number of Britons who claim to take horoscopes "very seriously" or "seriously" is 6 percent; about that many Americans say they act on horoscopes.

Similarly, the number of Britons who say they are serious or very serious about practices like touching wood or not walking under ladders is about 18 percent. As suggested above, reports of this kind are likely to be understated.

PUBLIC ATTITUDES

It is valuable to know the level of public science and technology literacy, as discussed above, but it is also important to know the feelings the public has about science and technology. In a democratic society, decisionmakers need to be aware of the degree to which the public supports certain S&T-related policies. It is equally important for those professionally involved with S&T to know the areas in which they have much or little public support. This section discusses the attitudes of the U.S. public toward science in general, its attitudes toward scientists, and its attitudes regarding some specific areas of policy that concern science and technology. Where possible, comparisons are made with earlier U.S. data and with the data recently obtained in the parallel British survey.

Attitudes Toward Science in General

Questions about the public's overall approval or disapproval of science have been asked in national surveys at least since 1957. In that year, the National Association of Science Writers sponsored a major survey of public interest, attitudes, information acquisition, and information needs regarding science.[38] This survey was the benchmark for all later studies, since it was performed just before the launching of Sputnik and the consequent changes in American attitudes and policies regarding S&T.

One of the 1957 questions that asked about general public support for science was repeated in the 1988 survey. (See text table 8-9.) Interestingly, there was virtually no change between the two surveys in the high percentage of respondents who believed that the world is better off

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[36] The British question asked respondents to place astrology on a 5-point scale, ranging from 1 for "not at all scientific" to 5 for "very scientific." Twelve percent scored astrology 5, and 14 percent scored it 4. Therefore, between 12 percent and 26 percent of Britons gave an answer equivalent to "very scientific" in the American version of the question.

[37] Sixty-three percent of Americans, but 72 percent of Britons, say they read horoscopes at least sometimes.

[38] See Survey Research Center (1958).

Text table 8-9. U.S. and British assessments of the benefits and harms due to science

United States	1957	1988
	– Percent –	
"All things considered, would you say that the world is better off or worse off because of science?"		
Better	88	88
Both[1]	3	4
Worse	3	7
Don't know/no answer	6	1
N =	1,919	999
"Science will solve our social problems like crime and mental illness.		
Agree	47	23
Disagree	45	75
Don't know/no answer	8	2
N =	1,919	1,481
Britain		
"The benefits of science are greater than any harmful effects."		
Agree	NA	44
Neither	NA	18
Disagree	NA	32
Don't know/no answer	NA	6
N =		2,009

NA = Not asked.

[1] Volunteered by respondent.

SOURCES: Survey Research Center (1958); Miller (1989a); Oxford (1988); and NORC (1988), 366.

See appendix table 8-9.

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Text table 8-10. U.S. and British publics' assessment of the effects of science on everyday values

	U.S.		Britain
	1957	1988	1988
	—— Percent ——		
a. "Science is making our lives healthier, easier, and more comfortable."			
Agree	94	85	73
Neither	—	—	12
Disagree	3	13	14
Don't know/no answer	3	2	1
b. "Science makes our way of life change too fast."			
Agree	43	40	49
Neither	—	—	16
Disagree	51	59	32
Don't know/no answer	6	2	3
c. "One of the bad effects of science is that it breaks down people's ideas of right and wrong."			
Agree	23	33	NA
Disagree	67	61	NA
Don't know/no answer	10	6	NA
d. "We depend too much on science and not enough on faith."			
Agree	50	51	44
Neither	13	—	19
Disagree	21	43	34
Don't know/no answer	16	6	2
N =	1,919	2,041	2,009

NA = This question not asked these respondents; — = this option not offered these respondents.

Note: For variations in question wording, see appendix table 8-10.

See appendix table 8-10.

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because of science. This consistency remains despite a long time lapse and the many events involving S&T that have occurred in public life, such as technological accidents, increased awareness of environmental pollution, and new medical discoveries.

Of course, some attitudes have changed over the 31-year period. For example, the number of people who believe that science will solve social problems like crime and mental illness has dropped significantly. (See text table 8-9.) This may reflect a more realistic contemporary view of the powers of science, but the public still does not withhold its overall support. The same conclusion can be drawn from the responses to two other questions that compare the benefits with the harms due to science. (See appendix table 8-9.) During the 1972-88 period, there have been yearly fluctuations, but—overall—the public overwhelmingly believes that the benefits of science outweigh the harmful effects.

A similar, though not identical, question about the benefits of science was asked in the British survey. (See text table 8-9.) There are enough negative responses to suggest strongly that the British public is not as convinced of the benefits of science as is the American public.

Four other questions repeated from 1957 also reflect broad public feelings about science. (See text table 8-10.) Substantial majorities of Americans continue to believe that science is making our lives healthier, easier, and more comfortable (question a) and that science does not break down people's ideas of right and wrong (question c). In both cases, however, there was less support for science in 1988 than in 1957. Apparently, the more negative sentiments actually developed between 1957 and 1979. Additional data show that little change in the responses to these two questions is seen from 1979 to 1988. (See appendix table 8-10.)[39]

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[39] Since appendix table 8-9 shows virtually no change in the level of public support for science in the 1970s, it seems fair to say that any decline in public support took place sometime between 1957 and 1972.

As for whether science makes our way of life change too fast (question b), and whether we depend too much on science and not enough on faith (question d), the numbers who reject these negative assessments may actually have increased slightly from 1957 to 1988. This would be a positive development in public opinion toward science.[40]

Britons are more likely than Americans to agree that science makes our way of life change too fast (question b); also, fewer Britons seem to agree that science makes our lives healthier, easier, and more comfortable (question a).[41] (See text table 8-10.) These results are consistent with those on text table 8-9, and reflect the fact that Americans express more positive overall assessments. In general, the support of science on the part of the U.S. public—when expressed in very broad terms—seems to have held up quite well since 1957, though dissenting opinions increased in some areas between 1957 and 1979.

Attitudes Toward Scientists

The public's broad feelings about scientists are also of interest. For example, when students are deciding whether to pursue a career in science, the general picture they or their parents have of scientists as persons may influence their choice. Also, the scientific community issues various kinds of information and/or warnings to the public in connection with health and diet, environmental pollution, energy sources, the need for funding different research facilities, etc. The public's acceptance of these communications can be affected by the level of confidence it has in scientists and its attitudes about them.

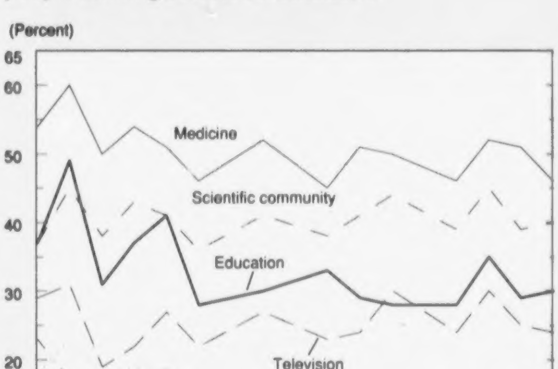
One measure of the public's view of scientists is the degree of confidence it has in leaders of the scientific community compared with those in other public institutions. (See figure 8-1.) This indicator is understood to represent the level of confidence in the institutions themselves.[42]

Since 1973, the scientific community has almost always ranked second only to medicine among the 13 institutions surveyed. (For the entire list of institutions, see appendix table 8-11.) This is a strong indication of support for science; more so since medicine is also a highly science-oriented profession. While there are distinct year-to-year fluctuations, the general trend is that the average level of confidence in all these institutions has decreased since the early 1970s. During this time, the scientific community has gained in relation to the average for all institutions. (See appendix text table 8-11.)

Other results allow current attitudes toward scientists to be compared with those expressed in 1957. (See text table 8-11.) A large majority agrees that most scientists want to work on things that will make life better for the average person, and a substantial majority disagrees with the statement that scientists are prying into things they ought to stay out of. For both statements, however, support for science was lower in 1988 than in 1957. This is consistent with the earlier results that show public support remaining high, but not as high as in 1957. Another question asked whether scientific researchers have a power that makes them dangerous. Again, a majority rejected the critical opinion in 1988. In 1985, however, a majority believed that scientists are dangerous.

These questions are useful for identifying trends in the general public feeling about scientists and also for identifying those groups within the public that are less supportive of science. For example, suspicion of the power of scientists was strongly dependent on level of education in 1988, with 52 percent of those lacking a high school diploma believing that scientists are dangerous. Similarly, there is a dependence on age: 48 percent of those over age 65 take that view. Those least likely to consider scientists dangerous are college-educated, aged 25 to 34, and male.

Figure 8-1.
Percentage of public expressing great confidence in people running selected institutions



See appendix table 8-11.

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[40] In early 1988, the National Opinion Research Center fielded two questions identical with those on text table 8-10. The responses—obtained by personal interview rather than by telephone and with a different sample—were very similar to those on the table and lend support to the quality of the present data. To question b, the responses were:

- Agree—40 percent,
- Disagree—58 percent, and
- Don't know/no answer—2 percent.

To question c, the responses were:

- Agree—32 percent,
- Disagree—65 percent, and
- Don't know/no answer—3 percent.

The sample size was 1,481. See NORC (1988), p. 366.

[41] Comparison is complicated by the existence of the middle response category in the British, but not the American, administration of these questions. The middle category does not affect the great difference between the U.S. and British responses on question b, and it probably does not on question a. In the case of question d, however, the large percentage responding "neither" on the British survey precludes comparison with the U.S. result.

[42] Smith (1981).

Text table 8-11. Public attitudes toward scientists

	1957	1988
	– Percent –	
"Most scientists want to work on things that will make life better for the average person."		
Agree	90	80
Disagree	5	17
Don't know/no answer	5	3
N =	1,919	2,041
"Scientists always seem to be prying into things they really ought to stay out of."		
Agree	22	34
Disagree	70	64
Don't know/no answer	8	2
N =	1,919	1,481
	1985	1988
"Because of their knowledge, scientific researchers have a power that makes them dangerous."		
Agree	55	38
Disagree	42	59
Don't know/no answer	4	3
N =	2,005	2,041

SOURCES: Survey Research Center (1958); Miller (1985); Miller (1989a); NORC (1988).

Science & Engineering Indicators—1989

Text table 8-12. U.S. public's view of dangerous powers possessed by scientists: 1988

Area mentioned	Percent mentioning
Nuclear	11
Biological	5
Weapons (nonnuclear)	4
Individual quirks	1
Chemicals	1
Environmental effects	1
Religion	1
Vague, no answer	13
Not asked[1]	62
N =	2,041

"When you think about scientific researchers who have powers that make them dangerous, what kinds of powers do you have in mind?"

[1] Question was asked only of those who had previously answered that scientific researchers have a power that makes them dangerous.

Note: A fuller statement of the responses comprised under these headings is given in appendix table 8-12.

SOURCE: Miller (1989a).

Science & Engineering Indicators—1989

Those 1988 respondents who considered scientists to have dangerous powers (38 percent of those interviewed) were further asked what these dangerous powers were. A large portion could not give a definite answer. (See text table 8-12.) Of the answers given, the most commonly mentioned area by far had to do with nuclear power, nuclear weapons, and radiation. There was also some mention of biological research and weapons in general.

Attitudes About Specific Policy Areas

A number of specific policy areas were selected for special study. These supplement the broad questions discussed above by moving away from science in general into matters of practical concern. One issue is whether people express the same level of support for science when specifics are involved rather than broad notions regarding science in general.

Priorities for Public Spending. One measure of public support for science is whether the public wishes the government to spend more for it. The U.S. public was asked about this in 1981 and again in 1988. (See text table 8-13.) Scientific research was put on a list of possible areas for public funding, in order to compare the public's interest in more science with its interest in other important matters that call for government funding. As the table shows, the public considers several other areas of public policy to require increased funding more urgently than does pure science. Some of these areas—like reducing pollution and improving health care—require the application of science. From 1981 to 1988, there was a substantial increase in public interest in improving education, reducing pollution, improving health care, and helping low-income persons. By contrast, the level of support for more pure science funding changed hardly at all over this period.

The space program, which is also S&T-related, has lower public support than scientific research as such. Public interest in supporting the space program also did not change much from 1981 to 1988. On the other hand, there was a large drop in the percentage of the public who wished to see more defense expenditures.[43]

More detailed information shows that of all the fields listed, the public is most neutral about science. (See appendix table 8-13.) Scientific research is the only policy area in which more people feel that the "right amount" is being spent, rather than either "too much" or "too little." Negative reactions are frequently expressed for space exploration and national defense, while most people want more spending in the other areas. The lukewarm reaction to more science spending may reflect the general feeling that science is a good thing, but not as appealing as other areas

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[43] An experiment was run in the 1988 survey to see whether the wording of the question about defense had a significant effect on the response. (See text table 8-13.) The results show that there seems to be some effect: the public dislikes the notion of "weapons." In any case, the drop in interest in defense spending from 1981 to 1988 appears to be substantial regardless of wording.

Text table 8-13. U.S. and British public support for increased government spending on certain problems

Problem area	U.S. 1981	U.S. 1988	Britain 1988
	— Percent —		
Helping older people	73	76	80
Improving education	61	76	78
Reducing pollution	52	76	64
Improving health care	60	67	85
Helping low-income persons	44	55	72
Supporting scientific research	32	34	47
Exploring space	18	17	12
Developing and improving weapons for national defense	33	NA	NA
Improving national defense[1]	NA	17	NA
Developing weapons for national defense[1]	NA	11	7
N =	1,655	2,041	2,009

"We are faced with many problems in this country. I'm going to name some of these problems, and for each one, I'd like you to tell me if you think that the government is spending too little money on it, about the right amount, or too much."

NA = Not asked.

Note: Wording shown is for 1988 U.S. survey. Slightly different wording was used in 1981 and British survey.

[1] In 1988, the U.S. sample was divided, so that 999 answered this question with the first wording, and 1,042 answered it with the second wording.

SOURCES: Miller (1982), table 13; Miller (1989a); and Oxford (1988).

See appendix table 8-13.

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where the usefulness of spending is more direct and immediate.

A related question asked the American respondents "Even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Federal Government." Eighty-one percent of the respondents agreed with this (79 percent in 1985); this shows overwhelming support for the idea that basic research is a suitable subject for Federal support.

British respondents were also asked about the areas in which they would like to see more or less government funding. (See text table 8-13.) They showed especially high interest in improving health care and helping older people and little interest in weapons for national defense. With regard to scientific research, they seem to have a greater desire for increased government funding than Americans have.

Government Regulation of Various Areas of Science and Technology. Another area in which the public can express its feeling about science and technology has to do with its desire to see more or less regulation of them. The desire for more regulation is an expression of some kind of fear or concern. Substantial minorities of Americans think that more regulation is needed in some areas. (See text table 8-14.) Basic scientific research does not arouse as much concern as chemical food additives or nuclear power plants, which affect the public directly. However, about a quarter of the public would like to see more regulation of basic research, and the number wishing to see such regulation seems to have increased since 1985. The only instance in which the desire for more regulation has decreased involves new pharmaceutical products. This may be related to the increased public interest in the development and dissemination of drugs to treat AIDS and similar diseases.

In most cases, a majority or plurality of respondents believes that the present level of regulation is about right. (See appendix table 8-14.) The exception is food additives; here, a plurality wants more regulation. Food additives and nuclear power plants are also the areas in which there are large percentages on the side of both more and less regulation.

In terms of demographics:

- More women than men want to increase regulation of food additives; more women also want to decrease it. (Men tend to be neutral.)
- Young people (18 to 24 years old) especially want less regulation of nuclear power. They also definitely oppose regulation of food additives, while older people are definitely in favor.
- The effect of education is quite straightforward: better-educated people are less in favor of regulating either food additives or nuclear plant construction.

Attitudes About the Effects of Computers and Automation on Employment. One of the most personal ways in which science and technology can affect members of the public is in terms of employment—whether they make more or fewer jobs available and how they affect the nature of people's jobs. Concerns about the effects of "automation" and/or "robots" on the nature and availability of

Text table 8-14. Public support for more regulation of various areas of science and technology (Percent favoring more regulation)

Area	1985	1988
Use of chemical additives in foods	38	42
Construction of nuclear power plants	29	31
Conduct of genetic engineering research	20	25
Conduct of basic scientific research	17	23
Development of new pharmaceutical products	21	16
N =	2,005	2,041

"I'm going to read you a short list of activities and for each one I'd like for you to tell me whether you think that the present level of governmental regulation is too high, too low, or about right."

SOURCES: Miller (1985); Miller (1989a).

See appendix table 8-14.

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Text table 8-15. U.S. and British publics' attitudes toward computers and employment and animal research

	U.S.			Britain
	1983	1985	1988	1988
	Percent			
Computers and automation will create more jobs than they will eliminate.				
Agree	42	48	40	34
Neither[1]	NA	NA	NA	12
Disagree	52	44	52	50
Don't know	6	8	8	3
Research on animals should be permitted if it produces information about health.				
Agree	NA	63	53	36
Neither[1]	NA	NA	NA	9
Disagree	NA	30	42	53
Don't know	NA	7	5	2
N =	1,630	2,005	2,041	2,009

"On balance, computers and factory automation will create more jobs than they will eliminate."

1983 wording: "On balance, computers will create . . ."

British wording: "More jobs will be created than lost as a result of computers and factory automation."

"Scientists should be allowed to do research that causes pain and injury to animals like dogs and chimpanzees if it produces new information about health problems."

1985 wording: "Studies (should be permitted) that cause pain and injury to animals like dogs and chimpanzees, but which produce new information about human disease or health problems."

British wording: ". . . about human health problems."

NA = Not asked.

[1] This option was offered to respondents in the British survey but not in the U.S. surveys.

SOURCES: Miller (1983); Miller (1985); Oxford (1988); Miller (1989a).

See appendix table 8-15.

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work have been widely expressed in many countries for many years.[44]

On the overall question of whether computers and automation will create more jobs than they will eliminate, Americans' opinions have fluctuated. (See text table 8-15.) In 1988, a small majority believed that more jobs will *not* be created. This is very similar to the response expressed in 1983, but not in 1985. The British public appears to be slightly more skeptical than the American public as to whether computers and automation will create jobs.

Attitudes About Research on Animals. Extensive controversy surrounds the issue of scientific experimentation on animals. In some well-known instances, public resistance has prevented or slowed the construction of laboratory facilities for such research. The U.S. and British publics were asked their opinion as to whether research that may harm animals should be allowed if it produces new information about human health problems. (See text table 8-15.) In this context, a small majority of the American public favors animal research, though not as many as in 1985. In Britain, the majority opposes animal research.

Although a majority of Americans favors animal research, a substantial minority is opposed. Further data help to show where in the public the support and opposition are located. (See appendix table 8-15.) Respondents were asked whether they strongly agreed, or only generally agreed, that animal research should be allowed; or whether they strongly, or only generally, opposed it. The results show that not many in any demographic group strongly support animal research, but that there are some groups in which it is strongly opposed.

Opposition is strongest among women and in the youngest age group (i.e., those from 18 to 24 years of age). Support for animal research clearly increases in older age groups. The effect of education is unusual: people with only a high school diploma are more opposed to animal research than those with more—or less—education.

Public Support of Space Exploration and Nuclear Power. American respondents were asked to assess these two areas in terms of their benefits versus the costs or risks they entail. In both cases, the level of public support was about equal to the level of opposition. (See text table 8-16.) Also, in both cases there was slightly less public support in 1988 than in the previous survey in 1985. Men favor both space exploration and nuclear power to a

Text table 8-16. Public assessment of space exploration and nuclear power

Area and assessment	1985	1988
	- Percent -	
Space exploration		
Benefits greater than costs	53	47
Benefits equal costs[1]	2	3
Costs greater than benefits	40	44
Don't know	5	6
Nuclear power		
Benefits greater than risks	49	42
Benefits equal risks[1]	1	3
Risks greater than benefits	45	48
Don't know	4	8
N =	2,005	2,041

"In your opinion, have the costs of space exploration exceeded its benefits, or have the benefits of space exploration exceeded its costs?"

[1] Volunteered by respondents.

SOURCES: Miller (1985); Miller (1989a).

See appendix table 8-16.

Science & Engineering Indicators—1989

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[44] A more extensive discussion of public attitudes in this area, which compares U.S. with Japanese attitudes, can be found in NSB (1987), pp. 150-52.

greater extent than women do. (See appendix table 8-16.) Age does not have a strong effect on attitudes toward the space program, except that the oldest group (65 and older) is especially opposed. On the other hand, support for nuclear power increases among the older groups. Respondents with more education clearly give more endorsement to space exploration. With nuclear power, education is less significant, and there are large minorities in opposition even among college-educated respondents.

In 1985 and 1986, a study was made of the effect of the Challenger and Chernobyl accidents on public opinion. It showed that the Challenger accident in January 1986 had been followed by an immediate increase in public support for the *space program* in February 1986. By June 1986, that gain had slightly fallen off, when more information had been published about the causes of the accident and the Rogers Commission report had been issued.[45] More recent data show that by 1988, fewer people believed that the benefits of the space program exceed its costs than in November 1985, before the accident. (See appendix table 8-17.) Thus, in the case of the space program, the increased support at the time of the accident has dissipated, and the overall trend in support has been negative.

The Chernobyl accident in April 1986 had no immediate noticeable effect on Americans' assessment of the risk/benefit balance for *nuclear power*. Similar levels of support and opposition were seen in February 1986 and June 1986.[46] By July 1988, however, there had evidently been an erosion in public support for nuclear power. (See appendix table 8-17.) It is not clear how much of this is a delayed reaction to the Chernobyl accident.

The Challenger accident evidently produced an immediate shift in the levels of public support for *science in general*. From November 1985 to February 1986, there was an increase in those who felt that the benefits of scientific research exceed the harmful results. However, there was a sharp decrease in those who felt that the balance *strongly* favors beneficial results, with a corresponding increase in those who felt the balance is *only slightly* in favor of beneficial results. This shift persisted in June 1986, but by 1988, it was gone and the levels of support expressed in November 1985 had reappeared. (See appendix table 8-17.) In this case, the Challenger—and perhaps also the Chernobyl—accident had a transient effect on public opinion.

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[45] See NSB (1987), pp. 162-65.

[46] Ibid.

REFERENCES

American Association for the Advancement of Science (AAAS). 1989. *Science for All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics, and Technology*. Washington, DC: AAAS.

Commission of the European Communities (CEC). 1989. "Eurobaromètre No. 31, L'Opinion Publique dans la Communauté Européene." Brussels: Commission of the European Communities, Directorate-General for Information, Communication, Culture.

Durant, J., G. Evans, and G. Thomas. 1989. "The Public Understanding of Science." *Nature* 340 (6 July): 11-14.

Evans, G., and J. Durant. 1989. "Public Understanding of Science in Britain and the USA." In *British Social Attitudes: International Comparisons*, edited by R. Jowell, S. Witherspoon, and L. Brook. Aldershot, United Kingdom: Gower Press.

Lightman, A.P., and J.D. Miller. 1989. "Contemporary Cosmological Beliefs." *Social Studies of Science* 19: 127-36.

Miller, J.D. In press, 1990. *Scientific Literacy in the United States*. New York: Plenum Press.

_____. Forthcoming, 1989a. "Attitudes of the U.S. Public Toward Science and Technology: 1988." Report to the National Science Foundation.

_____. 1989b. "Scientific Literacy." Paper presented at the annual meeting of American Association for the Advancement of Science, San Francisco, January 17, 1989.

_____. 1985. Survey of the attitudes of the U.S. public toward science and technology, unpublished tabulations. DeKalb, IL: Public Opinion Laboratory, Northern Illinois University.

_____. 1983. "A National Survey of Adult Attitudes Toward Science and Technology in the United States." Report prepared for the Annenberg School of Communications, University of Pennsylvania.

_____. 1982. "A National Survey of Public Attitudes Toward Science and Technology." Report to the National Science Foundation. DeKalb, IL: Northern Illinois University.

Miller, J.D., K. Prewitt, and R. Pearson. 1980. "The Attitudes of the U.S. Public Toward Science and Technology: Analytic Report." Report to the National Science Foundation. Chicago: National Opinion Research Center, University of Chicago.

National Opinion Research Center (NORC). 1988. *General Social Surveys, 1972-1988: Cumulative Codebook*. Principal Investigator, J.A. Davis; Director and Co-Principal Investigator, T.W. Smith. Chicago: NORC, University of Chicago.

National Science Board (NSB). 1987. *Science & Engineering Indicators—1987*. NSB 87-1. Washington, DC: Government Printing Office.

Oxford University Department for External Studies and Social and Community Planning Research, London. 1988. Survey of the public understanding of science in Britain.

Smith, T.W. 1981. "Can We Have Confidence in Confidence? Revisited." In *Special Demographic Analyses, Measurement of Subjective Phenomèna*, U.S. Bureau of the Census. Washington, DC: Government Printing Office.

Survey Research Center. 1958. "The Public Impact of Science in the Mass Media: A Report on a Nation-Wide Survey for the National Association of Science Writers." Ann Arbor, MI: Institute for Social Research, University of Michigan.

Appendix I
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Appendix table 1-1. Achievement scores in science, by age, gender, and ethnicity: 1970-86

Gender and ethnicity	1970	1973	1977	1982	1986
			9-year-olds		
Total	224.9	220.3	219.9	220.9	224.3
Male	227.6	222.5	222.1	221.0	227.3
Female	222.7	218.4	217.7	220.7	221.3
White	235.9	231.1	229.6	229.1	231.9
Black	178.7	176.5	174.9	187.1	196.2
Hispanic	NA	NA	191.9	189.0	199.4
			13-year-olds		
Total	254.9	249.5	247.4	250.2	251.4
Male	256.8	251.7	251.1	255.7	256.1
Female	253.0	247.1	243.8	245.0	246.9
White	263.4	258.6	256.1	257.3	259.2
Black	214.9	205.3	208.1	217.2	221.6
Hispanic	NA	NA	213.4	225.5	226.1
			17-year-olds		
Total	304.8	295.8	289.6	283.3	288.5
Male	313.8	304.3	297.1	291.9	294.9
Female	296.7	288.3	282.3	275.2	282.3
White	311.8	303.9	297.7	293.2	297.5
Black	257.8	250.4	240.3	234.8	252.8
Hispanic	NA	NA	262.3	248.7	259.3

NA = Not available.

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988).

See figures 1-1, 1-2, 1-3, and 1-4; figure O-12 in Overview; and text table 1-1.

Science & Engineering Indicators—1989

Appendix table 1-2. Levels of scientific proficiency used in the National Assessment of Educational Progress to classify student achievement scores

Level of classification	Definitions
Knows everyday science facts	Students at this level know some general scientific facts of the type that could be learned from everyday experiences. They can read simple graphs, match the distinguishing characteristics of animals, and predict the operation of familiar apparatus that work according to mechanical principles.
Understands simple scientific principles	Students at this level are developing some understanding of simple scientific principles, particularly in the life sciences. For example, they exhibit some rudimentary knowledge of the structure and function of plants and animals.
Applies basic scientific information	Students at this level can interpret data from simple tables and make inferences about the outcomes of experimental procedures. They exhibit knowledge and understanding of the life sciences, including a familiarity with some aspects of animal behavior and ecological relationships. These students also demonstrate some knowledge of basic information from the physical sciences.
Analyzes scientific procedures and data	Students at this level can evaluate the appropriateness of the design of an experiment. They have more detailed scientific knowledge and the skill to apply their knowledge in interpreting information from text and graphs. These students also exhibit a growing understanding of principles from the physical sciences.
Integrates specialized scientific information	Students at this level can infer relationships and draw conclusions using detailed scientific knowledge from the physical sciences, particularly chemistry. They also can apply basic principles of genetics and interpret the societal implications of research in this field.

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988).

See text table 1-1.

Science & Engineering Indicators—1989

Appendix table 1-3. Percentages of 9-year-old students scoring at or above various science proficiency levels, by gender and ethnicity: 1977-86

Gender and ethnicity	1977	1982	1986
	Knows everyday science facts		
Total	93.6	95.0	96.3
Male	94.3	94.0	96.3
Female	92.9	96.0	96.3
White	97.8	98.1	98.5
Black	73.1	81.2	87.5
Hispanic	83.1	84.6	89.6
	Understands simple scientific principles		
Total	67.9	70.4	71.4
Male	69.3	69.3	72.7
Female	66.4	71.6	70.1
White	76.5	78.0	78.4
Black	27.7	38.7	45.1
Hispanic	42.1	41.8	49.1
	Applies basic scientific information		
Total	26.2	24.8	27.6
Male	27.6	25.9	29.4
Female	24.8	23.7	25.8
White	31.3	30.1	32.6
Black	8.5	4.4	10.7
Hispanic	3.8	3.8	8.8
	Analyzes scientific principles and data		
Total	3.5	2.2	3.4
Male	3.9	2.3	4.0
Female	2.9	2.1	2.7
White	4.3	2.7	4.3
Black	0.1	0.4	0.4
Hispanic	0.5	0.0	0.2

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988).

See text table 1-1.

Science & Engineering Indicators—1989

Appendix table 1-4. Percentages of 13-year-old students scoring at or above various science proficiency levels, by gender and ethnicity: 1977-86

Gender and ethnicity	1977	1982	1986
	Understands simple scientific principles		
Total	85.9	89.6	91.8
Male	87.1	91.6	92.9
Female	84.6	87.8	90.7
White	91.9	94.5	96.4
Black	57.1	66.8	74.3
Hispanic	63.1	74.5	76.1
	Applies basic scientific principles		
Total	49.2	51.5	53.4
Male	52.3	57.0	58.4
Female	46.1	46.3	48.4
White	56.7	58.7	61.9
Black	15.1	18.6	20.2
Hispanic	19.1	25.8	27.6
	Analyzes scientific procedures and data		
Total	10.9	9.4	9.4
Male	12.8	12.2	12.5
Female	9.1	6.8	6.4
White	13.1	11.2	11.8
Black	1.2	0.8	0.9
Hispanic	2.3	2.4	1.6
	Integrates specialized scientific information		
Total	0.7	0.4	0.2
Male	0.9	0.5	0.4
Female	0.5	0.2	0.1
White	0.9	0.4	0.3
Black	0.0	0.0	0.0
Hispanic	0.2	0.0	0.0

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No 17-S-01 (Princeton: Educational Testing Service, 1988).

See text table 1-1.

Science & Engineering Indicators—1989

Appendix table 1-5. Percentages of 17-year-old students scoring at or above various science proficiency levels, by gender and ethnicity: 1977-86

Gender and ethnicity	1977	1982	1986
	Understands simple scientific principles		
Total	97.2	95.8	96.7
Male	97.9	96.9	96.9
Female	96.6	94.8	96.6
White	99.2	98.7	98.6
Black	84.5	81.0	89.8
Hispanic	92.7	86.1	92.9
	Applies basic scientific principles		
Total	81.8	76.8	80.8
Male	85.4	81.5	83.1
Female	78.3	72.4	78.5
White	88.4	85.0	87.6
Black	40.9	36.5	52.9
Hispanic	61.7	46.6	61.6
	Analyzes scientific procedures and data		
Total	41.7	37.5	41.4
Male	49.1	45.6	49.3
Female	34.4	29.8	33.8
White	47.4	44.0	48.8
Black	8.3	6.7	12.3
Hispanic	19.1	12.5	15.5
	Integrates specialized scientific information		
Total	8.5	7.2	7.5
Male	11.7	11.0	10.3
Female	5.3	3.7	4.7
White	9.9	8.8	9.0
Black	0.6	0.1	1.0
Hispanic	2.0	1.4	0.5

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No 17-S-01 (Princeton: Educational Testing Service, 1988).

See text table 1-1.

Science & Engineering Indicators—1989

Appendix table 1-6. Achievement scores in mathematics, by age, gender, and ethnicity: 1973-86

Gender and ethnicity	1973	1978	1982	1986
	9-year-olds			
Total	219.1	218.6	219.0	221.7
Male	217.7	217.4	217.1	221.7
Female	220.4	219.9	220.8	221.7
White	224.9	224.1	224.0	226.9
Black	190.0	192.4	194.9	201.6
Hispanic	202.1	202.9	204.0	205.4
	13-year-olds			
Total	266.0	264.1	268.6	269.0
Male	265.1	263.6	269.2	270.0
Female	266.9	264.7	268.0	268.0
White	273.7	271.6	274.4	273.6
Black	227.7	229.6	240.4	249.2
Hispanic	238.8	238.0	252.4	254.3
	17-year-olds			
Total	304.4	300.4	298.5	302.0
Male	308.5	303.8	301.5	304.7
Female	300.6	297.1	295.6	299.4
White	310.1	305.9	303.7	307.5
Black	269.8	268.4	271.8	278.6
Hispanic	277.2	276.3	276.7	283.1

SOURCE: National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

See figures 1-5, 1-6, 1-7, and 1-8; figure O-13 in Overview; and text table 1-2.

Science & Engineering Indicators—1989

Appendix table 1-7. Levels of mathematics proficiency used in the National Assessment of Educational Progress to classify student achievement scores

Level of classification	Definitions
Simple arithmetic facts	Learners at this level know some basic addition and subtraction facts, and most can add two-digit numbers without regrouping. They recognize simple situations in which addition and subtraction apply. They also are developing rudimentary classification skills.
Beginning skills and understanding	Learners at this level have considerable understanding of two-digit numbers. They can add two-digit numbers but are still developing an ability to regroup in subtraction. They know some basic multiplication and division facts, recognize relations among coins, can read information from charts and graphs, and use simple measurement instruments. They are developing some reasoning skills.
Basic operations and beginning problem solving	Learners at this level have an initial understanding of the four basic operations. They are able to apply whole number addition and subtraction skills to one-step word problems and money situations. In multiplication, they can find the product of a two-digit number and a one-digit number. They can also compare information from graphs and charts and are developing an ability to analyze simple logical relations.
Moderately complex procedures and reasoning	Learners at this level are developing an understanding of number systems. They can compute with decimals, simple fractions, and commonly encountered percents. They can identify geometric figures, measure lengths and angles, and calculate areas of rectangles. These students are also able to interpret simple inequalities, evaluate formulas, and solve simple linear equations. They can find averages, make decisions on information drawn from graphs, and use logical reasoning to solve problems. They are developing the skills to operate with signed numbers, exponents, and square roots.
Multi-step problem solving and algebra	Learners at this level can apply a range of reasoning skills to solve multi-step problems. They can solve routine problems involving fractions and percentages, recognize properties of basic geometric figures, and work with exponents and square roots. They can solve a variety of two-step problems using variables, identify equivalent algebraic expressions, and solve linear equations and inequalities. They are developing an understanding of functions and coordinate systems.

SOURCE: National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

See text table 1-2.

Science & Engineering Indicators—1989

Appendix table 1-8. Percentages of 9-year-old students scoring at or above various mathematics proficiency levels, by gender and ethnicity: 1978-86

Gender and ethnicity	1978	1982	1986
	Simple arithmetic facts		
Total	96.5	97.2	97.8
Male	95.9	96.8	97.7
Female	97.2	97.6	98.0
White	98.3	98.6	98.9
Black	87.8	90.4	93.0
Hispanic	93.5	95.0	96.4
	Beginning skills and understanding		
Total	70.3	71.5	73.9
Male	68.7	68.8	74.0
Female	71.9	74.2	73.9
White	76.0	76.9	79.2
Black	42.5	46.7	53.3
Hispanic	54.3	55.0	58.7
	Basic operations and beginning problem solving		
Total	19.4	18.7	20.8
Male	18.9	18.2	20.6
Female	19.8	19.2	20.9
White	22.5	21.5	24.5
Black	4.3	4.5	5.4
Hispanic	10.8	9.2	8.0
	Moderately complex procedures and reasoning		
Total	0.8	0.6	0.6
Male	0.7	0.6	0.6
Female	0.8	0.6	0.5
White	0.9	0.7	0.7
Black	0.0	0.0	0.0
Hispanic	0.5	0.0	0.0

SOURCE: National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

See text table 1-2.

Appendix table 1-9. Percentages of 13-year-old students scoring at or above various mathematics proficiency levels, by gender and ethnicity: 1978-86

Gender and ethnicity	1978	1982	1986
	Beginning skills and understanding		
Total	94.5	97.6	98.5
Male	93.8	97.3	98.3
Female	95.1	97.9	98.7
White	97.5	99.1	99.2
Black	79.5	89.0	95.5
Hispanic	85.9	96.1	96.1
	Basic operations and problem solving		
Total	64.9	71.6	73.1
Male	63.7	70.9	74.0
Female	66.1	72.3	72.3
White	72.9	78.5	78.7
Black	28.9	38.1	49.4
Hispanic	35.6	54.2	55.2
	Moderately complex procedures and reasoning		
Total	17.9	17.8	15.9
Male	18.3	19.2	17.6
Female	17.4	16.3	14.2
White	21.4	20.9	18.6
Black	2.1	3.3	4.0
Hispanic	3.4	6.2	5.4
	Multi-step problem solving and algebra		
Total	0.9	0.5	0.4
Male	1.0	0.7	0.6
Female	0.8	0.3	0.2
White	1.1	0.6	0.5
Black	0.0	0.0	0.1
Hispanic	0.1	0.2	0.3

SOURCE: National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

See text table 1-2.

Science & Engineering Indicators—1989

Appendix table 1-10. Percentages of 17-year-old students scoring at or above various mathematics proficiency levels, by gender and ethnicity: 1978-86

Gender and ethnicity	1978	1982	1986
	Beginning skills and understanding		
Total	99.8	99.9	99.9
Male	99.9	99.9	99.9
Female	99.7	99.9	99.9
White	100.0	100.0	99.9
Black	98.7	99.6	100.0
Hispanic	99.3	99.9	98.9
	Basic operations and problem solving		
Total	92.1	92.9	96.0
Male	93.0	93.9	96.5
Female	91.2	92.0	95.5
White	95.8	96.3	98.3
Black	70.0	75.3	86.0
Hispanic	77.4	81.3	90.8
	Moderately complex procedures and reasoning		
Total	51.4	48.3	51.1
Male	54.9	51.9	54.2
Female	48.0	44.9	48.1
White	57.3	54.5	58.0
Black	18.0	17.3	21.7
Hispanic	22.1	20.6	26.8
	Multi-step problem solving and algebra		
Total	7.4	5.4	6.4
Male	9.5	6.7	8.2
Female	5.5	4.1	4.5
White	8.6	6.3	7.6
Black	0.4	0.6	0.3
Hispanic	1.1	0.5	1.2

SOURCE: National Assessment of Educational Progress, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

See text table 1-2.

Science & Engineering Indicators—1989

Appendix table 1-11. Average achievement scores of 13-year-old students in mathematics, by gender and country: 1988

Country	Total	Male	Female
British Columbia	539.8	539.6	541.3
Ireland	504.3	508.2	499.6
South Korea	567.8	576.7	558.0
New Brunswick (English)	529.0	526.6	529.0
New Brunswick (French)	514.2	516.8	513.4
Ontario (English)	516.1	517.8	514.6
Ontario (French)	481.5	480.6	482.7
Quebec (English)	535.8	534.1	537.3
Quebec (French)	543.0	546.3	539.3
Spain	511.7	523.2	499.9
United Kingdom	509.9	507.0	512.5
United States	473.9	474.6	473.2

SOURCE: A.E. Lapointe, N.A. Mead, and G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science* (Princeton: Educational Testing Service, 1989).

See figure 1-9, and O-11 in Overview.

Science & Engineering Indicators—1989

Appendix table 1-12. Average achievement scores of 13-year-old students in science, by gender and country: 1988

Country	Total	Male	Female
British Columbia	551.3	562.3	541.6
Ireland	469.3	480.4	456.5
South Korea	549.9	567.5	530.6
New Brunswick (English)	510.5	517.2	502.3
New Brunswick (French)	468.1	477.4	460.2
Ontario (English)	514.7	524.3	504.7
Ontario (French)	468.3	474.9	463.1
Quebec (English)	515.3	525.4	505.7
Quebec (French)	513.4	523.7	502.1
Spain	503.9	518.0	489.5
United Kingdom	519.5	524.7	514.9
United States	478.5	481.9	474.9

SOURCE: A.E. Lapointe, N.A. Mead, and G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science (Princeton: Educational Testing Service, 1989).*

See figure 1-10, and O-11 in Overview.

Science & Engineering Indicators—1989

Appendix table 1-13. Levels of mathematics proficiency used in the International Assessment of Mathematics and Science to classify student achievement scores: 1988

Level of classification	Definitions
Perform simple addition and subtraction	Students at this level can add and subtract two-digit numbers without regrouping and solve simple number sentences involving these operations.
Use basic operations to solve simple problems	Students at this level can select appropriate basic operations (addition, subtraction, multiplication, and division) needed to solve simple one-step problems. They are capable of evaluating simple expressions by substitution and solving number sentences. They can locate numbers on a number line and understand the most basic concepts of logic, percent, estimation, and geometry.
Use intermediate level mathematics skills to solve two-step problems	Students at this level show growth in all mathematics topics in the assessment. They demonstrate an understanding of the concept of order, place value, and the meaning of remainder in division; they know some properties of odd and even numbers and of zero; and they can apply elementary concepts of ratio and proportion. They can use negative and decimal numbers; make simple conversions involving fractions, decimals, and percentages; and can compute averages. Students can use these skills to solve problems requiring two or more steps and can represent unknown quantities with expressions involving variables. Students can measure length, apply scales, identify geometric figures, calculate areas of rectangles, and are able to use information obtained from charts, graphs, and tables.
Understand measurement and geometry concepts and solve more complex problems	Students at this level know how to multiply fractions and decimals and are able to use a range of procedures to solve more complex problems. Students demonstrate an increased understanding of measurement and geometric concepts. They can measure angles found in simple figures, understand various characteristics of circles and triangles, can find perimeters and areas, and calculate and compare volumes of rectangular solids. Students are also able to recognize and extend number patterns.
Understand and apply more advanced mathematical concepts	Students at this level have the ability to deal with properties of the arithmetic mean and can use data from a complex table to solve problems. They demonstrate an increasing ability to apply school-based skills to out-of-school situations and problems.

SOURCE: A.E. Lapointe, N.A. Mead, and G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science* (Princeton: Educational Testing Service, 1989).

Science & Engineering Indicators—1989

Appendix table 1-14. Levels of science proficiency used in the International Assessment of Mathematics and Science to classify student achievement scores: 1988

Level of classification	Definitions
Know everyday science facts	Students at this level know some general scientific facts of the type that can be learned from everyday experiences. For example, they exhibit some rudimentary knowledge concerning the environment and animals.
Understand and apply simple scientific principles	Students at this level exhibit a growing knowledge in the life sciences.
Use scientific procedures and analyze scientific data	Students at this level have a grasp of experimental procedures used in science, such as designing experiments, controlling variables, and using equipment. They can identify the best conclusions drawn from data on a graph and the best explanation for observed phenomena. Students also understand some concepts in a variety of science content areas.
Understand and apply intermediate scientific knowledge and principles	Students at this level demonstrate an understanding of intermediate scientific facts and principles and can apply this understanding in designing experiments and interpreting data. They also can interpret figures and diagrams used to convey scientific information. Students at this level can infer relationships and draw conclusions by applying facts and principles, particularly from the physical sciences.
Integrate scientific information and experimental evidence	Students at this level can interpret experimental data that involve several variables. They also can interrelate information represented in a variety of forms—text, graphs, figures, and diagrams. Students can make predictions based on data and observations and are aware of limitations of extrapolation. Students demonstrate a growing understanding of more advanced scientific knowledge and concepts, such as definitions of a calorie or the concept of chemical change.

SOURCE: A.E. Lapointe, N.A. Mead, and G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science* (Princeton: Educational Testing Service, 1989).

Science & Engineering Indicators—1989

Appendix table 1-15. Percentages of 13-year-old students scoring at or above various mathematics proficiency levels, by country: 1988

Country	Proficiency levels				
	Perform simple addition & subtraction	Use basic operations to solve simple problems	Use intermediate level skills to solve two-step problems	Understand measurement & geometry concepts and solve more complex problems	Understand & apply more advanced math concepts
British Columbia	99.7	94.9	69.5	23.8	2.0
Ireland	98.3	86.3	54.7	14.2	0.8
South Korea	99.6	95.3	78.1	39.6	4.9
New Brunswick (English)	99.9	95.5	65.4	17.8	1.0
New Brunswick (French)	99.6	94.6	58.3	11.6	0.4
Ontario (English)	99.2	91.8	58.0	16.0	1.4
Ontario (French)	98.7	84.8	40.5	7.0	0.1
Quebec (English)	99.8	96.7	67.3	20.2	1.4
Quebec (French)	99.9	97.2	72.7	21.8	1.7
Spain	99.2	90.7	57.0	14.3	1.3
United Kingdom	98.5	86.7	55.5	18.4	2.5
United States	96.6	77.7	40.3	9.2	0.7

SOURCE: A.E. Lapointe, N.A. Mead, and G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science* (Princeton: Educational Testing Service, 1989).

Science & Engineering Indicators—1989

Appendix table 1-16. Percentages of 13-year-old students scoring at or above various science proficiency levels, by country: 1988

Country	Proficiency levels				
	Know everyday science facts	Understand & apply simple scientific principles	Use scientific procedures & analyze data	Understand & apply intermediate knowledge & principles	Integrate information & experimental evidence
British Columbia	99.7	95.2	71.9	30.6	4.1
Ireland	95.7	75.6	37.2	9.1	0.5
South Korea	99.7	93.1	72.7	32.6	2.3
New Brunswick (English)	99.2	90.4	55.4	14.9	1.0
New Brunswick (French)	98.0	77.9	35.3	6.8	0.4
Ontario (English)	98.8	90.8	55.9	17.1	1.8
Ontario (French)	98.0	78.8	34.8	6.1	0.2
Quebec (English)	99.5	91.8	57.4	14.8	1.5
Quebec (French)	99.6	91.5	56.3	15.2	0.8
Spain	99.1	88.0	53.5	12.2	0.6
United Kingdom	98.5	89.0	59.0	21.3	2.4
United States	95.8	78.3	41.8	11.8	1.4

SOURCE: A.E. Lapointe, N.A. Mead, G.W. Phillips, *A World of Differences: An International Assessment of Mathematics and Science* (Princeton: Educational Testing Service, 1989).

Science & Engineering Indicators—1989

Appendix table 1-17. Achievement scores of students taking biology in the terminal grade of high school, by country

Country	Mean achievement scores	Percentage of students taking biology	Average age of students
Australia	48.2	18	17.1
Canada (English)	45.9	28	18.2
England	63.4	4	18.0
Finland	51.9	45	18.7
Hong Kong (Form 6)	50.8	7	18.4
Hong Kong (Form 7)	55.8	4	19.2
Hungary	59.7	3	18.0
Italy	42.3	14	19.5
Japan	46.2	12	18.1
Norway	54.8	10	18.1
Poland	56.9	9	18.8
Singapore	66.8	3	18.0
Sweden	48.5	15	19.0
United States	37.9	6	17.5

Note: Tests were administered in 1986 in the U.S. and in 1983 in the other countries.

SOURCE: International Association for the Evaluation of Educational Achievement, *Science Achievement in 17 Countries: A Preliminary Report* (Oxford: Pergamon Press, 1988).

See figure 1-11.

Science & Engineering Indicators—1989

Appendix table 1-18. Achievement scores of students taking chemistry in the terminal grade of high school, by country

Country	Mean achievement scores	Percentage of students taking chemistry	Average age of students
Australia	46.6	12.0	17.3
Canada (English)	36.9	25.0	18.4
England	69.5	5.0	18.0
Finland	33.3	14.0	18.6
Hong Kong (Form 6)	64.4	14.0	18.4
Hong Kong (Form 7)	77.0	8.0	19.2
Hungary	47.7	1.0	18.1
Italy	38.0	2.0	19.3
Japan	51.9	16.0	18.2
Norway	41.9	15.0	18.1
Poland	44.6	9.0	18.7
Singapore	66.1	5.0	18.0
Sweden	40.0	15.0	18.1
United States	37.7	1.0	17.8

Note: Tests were administered in 1986 in the U.S. and in 1983 in the other countries.

SOURCE: International Association for the Evaluation of Educational Achievement, *Science Achievement in 17 Countries: A Preliminary Report* (Oxford: Pergamon Press, 1988).

See figure 1-12.

Science & Engineering Indicators—1989

Appendix table 1-19. Achievement scores of students taking physics in the terminal grade of high school, by country

Country	Mean achievement scores	Percentage of students taking physics	Average age of students
Australia	48.5	11	17.3
Canada (English)	39.6	19	18.4
England	58.3	6	18.0
Finland	37.9	14	18.6
Hong Kong (Form 6)	59.3	14	18.4
Hong Kong (Form 7)	69.9	8	19.2
Hungary	56.5	4	18.1
Italy	28.0	19	19.3
Japan	56.1	11	18.2
Norway	52.8	24	18.1
Poland	51.5	9	18.7
Singapore	54.9	7	18.0
Sweden	44.8	15	18.1
United States	45.5	1	17.8

Note: Tests were administered in 1986 in the U.S. and in 1983 in the other countries.

SOURCE: International Association for the Evaluation of Educational Achievement, *Science Achievement in 17 Countries: A Preliminary Report* (Oxford: Pergamon Press, 1988).

See figure 1-13.

Science & Engineering Indicators—1989

Appendix table 1-20. Understanding of computer applications, by grade level: 1986

Type of application	Grade 3	Grade 7	Grade 11
	Percent		
Word processing	31.0	52.8	72.2
Graphics	34.7	50.4	60.7
Data bases	40.0	43.8	53.4
Spreadsheets	NA	44.4	31.0

NA = Not available.

SOURCE: National Assessment of Educational Progress, *Computer Competence: The First National Assessment*, Report No. 17-CC-01 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-21. Frequency of computer usage, by subject area: 1986

How often do you use a computer to:	Almost every day	Several times a week	About once a week	Less than once a week	Never
	Grade 7				
	Percent				
Practice math	5.7	4.7	9.8	17.5	62.3
Practice reading	3.1	3.8	5.9	8.8	78.4
Practice spelling	2.8	3.3	7.8	10.0	76.1
Do science problems	1.9	2.9	3.1	6.8	85.3
Learn and make music	2.4	3.0	6.2	10.3	78.1
Play games	19.4	15.4	16.3	24.6	24.3
	Grade 11				
	Percent				
Practice math	3.4	3.0	3.6	12.1	77.9
Practice reading	1.8	2.1	2.0	6.9	87.2
Practice spelling	1.4	1.6	2.8	6.7	87.5
Do science problems	0.8	1.5	1.9	8.6	87.2
Learn and make music	1.4	1.7	2.2	9.0	85.6
Play games	8.5	9.8	14.0	33.9	33.8

SOURCE: National Assessment of Educational Progress, *Computer Competence: The First National Assessment*, Report No. 17-CC-01 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-22. Percentages of college-bound seniors taking the SAT who intend to major in science and engineering, by discipline: 1977-88

Field	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	Percent											
Total	10.0	11.6	12.9	14.1	15.7	17.9	19.6	18.8	16.6	15.1	14.5	13.5
Mathematics and statistics	1.3	1.3	1.1	1.0	1.0	0.9	0.9	1.0	1.0	0.8	0.7	0.6
Computer science	1.3	1.8	2.4	3.0	4.1	5.7	7.5	7.2	5.2	3.7	3.0	2.7
Physical sciences	0.9	0.9	0.9	1.0	0.9	0.9	0.8	0.9	0.9	0.8	0.8	0.8
Engineering	6.5	7.6	8.4	9.2	9.7	10.4	10.3	9.8	9.5	9.8	10.0	9.3

SOURCES: Educational Testing Service (ETS), *Trends in SAT Scores and Other Characteristics of Examinees Planning to Major in Mathematics, Science, or Engineering;* and *ETS Policy Notes* vol. 1, no. 3 (1989).

See figure 1-14.

Science & Engineering Indicators—1989

Appendix table 1-23. Percentages of high-ability minority students saying certain high school experiences were of medium or great influence[1]

Experience	Percent
Science, mathematics clubs	24
College-based minority MSE recruitment/enrichment program	22
Honors courses in science	52
Science fair/independent research project	14
Advanced Placement mathematics	41
Honors courses in mathematics	57
Career fairs or mathematics/science career service days	26
Special mathematics/science or college preparatory magnet schools	20
Minority professional recruitment program: e.g., Society of Black/Hispanic Engineers	16

MSE = Mathematics/science/engineering.

[1] In their decision to continue studying mathematics or science in college.

SOURCE: T.L. Hilton, J. Hsia, D.G. Solorzano, and N.L. Benton, *Persistence in Science of High-Ability Minority Students*, Research Report No. RR-89-28 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-24. Percentages of high school graduates earning credits in mathematics, by gender: 1982 and 1987

	Total		Male		Female	
Course taken	1982	1987	1982	1987	1982	1987
Any mathematics	97.4	99.5	97.6	99.4	97.3	99.6
Remedial mathematics	32.7	24.5	35.9	26.4	29.6	22.8
Algebra 1	65.1	77.2	63.3	75.8	66.8	78.5
Algebra 2	35.1	46.1	35.3	44.1	34.9	47.9
Geometry	45.7	61.0	45.0	61.1	46.4	60.8
Trigonometry	12.0	20.4	12.9	21.9	11.3	19.0
Analysis/pre-calculus	5.8	12.4	6.0	13.5	5.5	11.3
Calculus	4.7	6.1	5.3	7.6	4.2	4.7
AP calculus	1.5	3.1	1.7	3.5	1.3	2.7
Statistics/probability	0.3	0.5	0.5	0.4	0.2	0.6

SOURCE: Westat, Inc., *Tabulations for the Nation At Risk Update Study as Part of the 1987 High School Transcript Study* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 1988).

Science & Engineering Indicators—1989

Appendix table 1-25. Percentages of high school graduates earning credits in science, by gender: 1982 and 1987

	Total		Male		Female	
Course taken	1982	1987	1982	1987	1982	1987
Any science	95.2	99.1	94.8	98.8	95.6	99.4
Biology	75.3	89.6	73.3	88.5	77.1	90.8
AP/honors biology	6.6	3.0	6.1	3.1	7.1	2.8
Chemistry	30.8	45.4	31.7	46.3	30.0	44.5
AP/honors chemistry	2.9	3.1	3.5	3.4	2.4	2.7
Physics	13.9	20.1	18.2	25.3	10.0	15.0
AP/honors physics	1.1	1.8	1.4	2.8	0.7	0.9
Engineering	0.1	0.1	0.2	0.2	0.0	0.1
Astronomy	1.1	0.8	1.2	0.8	1.0	0.7
Geology	13.9	15.0	14.8	15.8	13.0	14.2

SOURCE: Westat, Inc., *Tabulations for the Nation At Risk Update Study as Part of the 1987 High School Transcript Study* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 1988).

Science & Engineering Indicators—1989

Appendix table 1-26. Mean number of credits earned by high school graduates in science and mathematics, by race/ethnicity: 1982 and 1987

	Science		Mathematics		Computer science	
Race/ethnicity	1982	1987	1982	1987	1982	1987
White	2.27	2.68	2.59	2.97	0.12	0.43
Black	1.99	2.41	2.44	2.92	0.10	0.36
Hispanic	1.79	2.39	2.22	2.82	0.07	0.35
Asian/Pacific Islander	2.56	3.23	3.11	3.79	0.19	0.56
Other	2.02	2.57	2.21	3.01	0.05	0.31
Race not reported	NA	2.55	NA	3.03	NA	0.48

NA = Not available.

SOURCE: Westat, Inc., *Tabulations for the Nation At Risk Update Study as Part of the 1987 High School Transcript Study* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 1988).

See figure 1-16.

Science & Engineering Indicators—1989

Appendix table 1-27. Mean number of credits earned by high school graduates in selected subjects, by gender: 1982 and 1987

Subject	Total		Male		Female	
	1982	1987	1982	1987	1982	1987
English	3.80	4.05	3.76	4.03	3.84	4.07
History	1.68	1.91	1.68	1.93	1.69	1.89
Social studies	1.42	1.44	1.41	1.42	1.43	1.47
Mathematics	2.54	2.98	2.61	3.04	2.46	2.93
Computer science	0.11	0.42	0.13	0.46	0.10	0.39
Science	2.19	2.63	2.25	2.69	2.13	2.57
Foreign language	1.05	1.47	0.86	1.30	1.23	1.63

SOURCE: Westat, Inc., *Tabulations for the Nation At Risk Update Study as Part of the 1987 High School Transcript Study* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 1988).

See figure 1-15.

Science & Engineering Indicators—1989

Appendix table 1-28. Distribution of class ability level, by ethnic/racial enrollment of schools: 1986

Ethnic/racial enrollment of school	Teacher perception of class ability in science and mathematics: Mixed ability	Low ability	Average ability	High ability
	Percent			
Less than 10 percent white	20	36	48	16
10 to 50 percent white	19	25	45	30
50 to 90 percent white	21	22	41	37
More than 90 percent white	20	16	42	43

SOURCE: J. Oakes, T. Ormseth, B. Bell, and P. Camp, *The Distribution of Opportunities to Learn Mathematics and Science*, Preliminary unpublished paper (The RAND Corporation, n.d.).

Science & Engineering Indicators—1989

Appendix table 1-29. Average minutes per day spent on various subjects by elementary school teachers, by grade range: 1977 and 1986

Subject and grade range	1977	1986
Science		
K-3	17	18
4-6	28	29
Mathematics		
K-3	41	43
4-6	51	52
Social studies		
K-3	21	18
4-6	34	33
Reading		
K-3	95	77
4-6	66	63

Note: Data are for self-contained classes only.

SOURCE: I.R. Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, 1987).

See figure 1-17.

Science & Engineering Indicators—1989

Appendix table 1-30. Classroom time spent by teachers with a class during a typical week: 1986

Use of time	Grade 3	Grade 7
	—Percent of teachers—	
Providing instruction in science		
None	6	0
Less than 1 hour	15	1
1 to 2 hours	49	16
3 to 4 hours	24	69
5 hours or more	5	14
Maintaining order & disciplining students		
None	2	5
Less than 1 hour	54	72
1 to 2 hours	22	20
3 to 4 hours	5	1
5 hours or more	17	1
Administering tests or quizzes, grading tests, in-class work, and homework		
None	0	0
Less than 1 hour	8	44
1 to 2 hours	26	49
3 to 4 hours	20	5
5 hours or more	45	0

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-31. Classroom instructional practices in science: 1986

Instructional practice	Frequency			
	Daily	Weekly	Less than once a week	Never
	Percent			
Grade 3				
Go on a field trip	NA	3	31	55
Do experiments	11	30	26	19
Read science textbook	33	27	11	15
Do an oral or written report	20	16	17	33
Grade 7				
Lecture	31	39	13	18
Go on a field trip	1	2	16	82
Do experiments alone	3	18	29	50
Do experiments with other students	4	31	34	30
Read science textbook	43	39	8	9
Write up experiments	4	15	21	60
Do an oral or written report	3	16	35	46
Grade 11				
Lecture	55	33	3	8
Go on a field trip	2	27	25	46
Do experiments alone	0	0	14	86
Do experiments with other students	3	50	28	18
Read science textbook	28	42	12	18
Write up experiments	2	32	24	41
Do an oral or written report	2	13	34	52

NA = Not available.

SOURCE: National Assessment of Educational Progress, *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-32. Average science and mathematics proficiency by reported time spent on science and mathematics homework, grades 7 and 11: 1986

Time spent each week on science and math homework	Science		Mathematics	
	Percent	Proficiency	Percent	Proficiency
Grade 7				
No time	16	243	5	254
Less than 1 hour	47	251	43	265
1-2 hours	26	250	32	267
3-4 hours	8	254	12	276
More than 4 hours	3	251	8	270
Grade 11				
No time	12	285	7	296
Less than 1 hour	36	299	33	302
1-2 hours	31	304	30	309
3-4 hours	14	316	18	323
More than 4 hours	7	317	13	320

SOURCES: National Assessment of Educational Progress (NAEP), *The Science Report Card: Elements of Risk and Recovery*, Report No. 17-S-01 (Princeton: Educational Testing Service, 1988); and NAEP, *The Mathematics Report Card: Are We Measuring Up?*, Report No. 17-M-01 (Princeton: Educational Testing Service, 1988).

Science & Engineering Indicators—1989

Appendix table 1-33. Elementary school teachers meeting the standards of the National Science Teachers Association: 1986

Standard	Grades K-6 teachers
	—Percent—
Coursework in all three disciplines	35
With science methods	34
Without science methods	1
Coursework in two disciplines	40
With science methods	36
Without science methods	4
Coursework in one discipline	17
With science methods	15
Without science methods	2
No science coursework	5
With science methods	4
Without science methods	1
Unknown	3

Disciplines are: biological/life, physical, and earth/space sciences.

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-34. Elementary school teachers meeting the standards of the National Council of Teachers of Mathematics: 1986

Standard	Grades K-6 teachers
	—Percent—
Meet all three course requirements	18
Lacking one requirement	69
Lacking two requirements	6
Lacking all requirements	2
Unknown	4

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-35. Middle/junior high school teachers meeting the standards of the National Science Teachers Association: 1986

Coursework	Grade 7-9 teachers
	—Percent—
Science, methods of teaching science	22
Science only	2
Science methods only	56
Neither science nor science methods	18
Unknown	2

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-36. Middle/junior high school teachers meeting the standards of the National Council of Teachers of Mathematics: 1986

Standard	Grades 7-9 teachers
	—Percent—
Coursework in all five areas of mathematics	14
With mathematics teaching methods and computer programming	10
Lacking computer programming	4
Lacking mathematics teaching methods	0
Lacking both	0
Coursework in four areas of mathematics	26
With mathematics teaching methods and computer programming	16
Lacking computer programming	8
Lacking mathematics teaching methods	1
Lacking both	1
Coursework in two or three areas of mathematics	35
With mathematics teaching methods and computer programming	11
Lacking computer programming	17
Lacking mathematics teaching methods	4
Lacking both	3
Coursework in zero or one area of mathematics	22
With mathematics teaching methods and computer programming	2
Lacking computer programming	14
Lacking mathematics teaching methods	2
Lacking both	3
Unknown	3

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-37. High school science teachers meeting the standards of the National Science Teachers Association, by discipline: 1986

Coursework	Discipline		
	Biology	Chemistry	Physics
	Percent[1]		
Science, methods of teaching science	29	31	12
Science only	4	3	0
Science methods only	54	53	70
Neither science nor science methods	12	12	18
Unknown	1	1	1

[1] Percentage of all high school teachers in the subject.

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-38. High school math teachers meeting the standards of the National Council of Teachers of Mathematics: 1986

Course	Grades 10-12 mathematics teachers
	—Percent—
All 10 NCTM-recommended mathematics courses	15
With mathematics teaching methods course and computer programming	12
Lacking computer programming	2
Lacking mathematics teaching methods	0
Lacking both methods and computer programming	0
8-9 NCTM-recommended mathematics courses	39
With mathematics teaching methods course and computer programming	27
Lacking computer programming	11
Lacking mathematics teaching methods	1
Lacking both methods and computer programming	1
5-7 NCTM-recommended mathematics courses	31
With mathematics teaching methods course and computer programming	16
Lacking computer programming	12
Lacking mathematics teaching methods	2
Lacking both methods and computer programming	1
0-4 NCTM-recommended mathematics courses	12
With mathematics teaching methods course and computer programming	3
Lacking computer programming	3
Lacking mathematics teaching methods	4
Lacking both methods and computer programming	3
Unknown	4

Note: Percentages may not add to 100 because of rounding.

SOURCE: I.R. Weiss, "Course Background Preparation of Science and Mathematics Teachers in the United States," in *Science Teaching: Making the System Work* (Washington, DC: American Association for the Advancement of Science, 1988).

Science & Engineering Indicators—1989

Appendix table 1-39. Predicted median length of retention (first spell) in teaching, by state and discipline

Teaching specialty	Period and state in which sample began teaching		
	North Carolina (1975-79)	Michigan (1972-75)	Colorado (1979, 1982)
	— Median number of years —		
Elementary school	13.5	16.4	6.6
Mathematics	7.9	7.4	4.4
Social studies	6.6	7.6	3.4
English	5.7	7.3	3.1
Biology	5.6	9.6	6.0[1]
Chemistry/physics	4.1	4.9	
Sample size	8,462	7,785	1,377

[1] Chemistry/physics teachers cannot be distinguished from biology teachers in the Colorado data.

SOURCE: R. J. Murnane and R. J. Olsen, "Will There Be Enough Teachers?," *AEA Papers and Proceedings* vol. 79, no. 2 (May 1989): 242-46.

Science & Engineering Indicators—1989

Appendix table 1-40. Percentage of teachers returning to the classroom after initially teaching less than 6 years, by state and discipline

Teaching specialty	North Carolina	Michigan	Colorado
	Percent returning		
Elementary school	28.1	33.0	30.0
Mathematics	22.6	29.1	23.1
Social studies	22.2	22.5	15.8
English	20.0	30.0	33.3
Biology	18.9	22.1	7.7[1]
Chemistry/physics	16.3	14.6	
All teachers	25.3	30.2	26.6
Sample size	3,177	4,815	289

[1] Chemistry/physics teachers cannot be distinguished from biology teachers in the Colorado data.

SOURCE: R. J. Murnane and R. J. Olsen, "Will There Be Enough Teachers?," *AEA Papers and Proceedings* vol. 79, no. 2 (May 1989): 242-46.

Science & Engineering Indicators—1989

Appendix table 2-1. Institutions of higher education, by Carnegie category, S/E and total degrees, and degree level: 1970, 1976, and 1986

				Degree level									
		All degrees		Associate		Bachelor's		First professional		Master's		Doctorate	
Carnegie category		S/E	Total	S/E	Total	S/E	Total	S/E	Total	S/E	Total	S/E	Total
		Number of institutions											
Total	1970	1,992	2,453	882	1,272	1,270	1,473	128	362	529	806	233	277
	1976	2,139	2,787	823	1,565	1,371	1,590	158	414	609	934	270	350
	1986	2,387	3,103	1,179	1,915	1,419	1,692	201	477	685	1,124	307	427
Doctorate	1970	175	176	60	87	172	172	75	111	171	173	170	172
	1976	185	186	39	76	182	183	89	125	183	184	182	183
	1986	213	214	50	81	205	208	103	144	210	210	205	211
Comprehensive	1970	401	406	95	158	398	404	9	46	242	315	19	26
	1976	543	545	84	228	542	544	10	59	302	402	31	48
	1986	559	559	160	287	556	559	21	69	339	457	38	66
Liberal arts	1970	570	617	30	87	561	608	1	29	50	123	4	11
	1976	493	540	27	147	489	533	1	18	41	96	3	9
	1986	532	563	87	207	526	561	2	26	55	171	6	13
2-year	1970	614	759	601	758	0	0	0	0	0	0	0	0
	1976	674	949	615	945	2	4	0	0	2	2	0	0
	1986	857	1,160	826	1,149	4	18	0	1	0	0	0	1
Specialized	1970	80	298	29	85	50	171	28	146	37	150	25	49
	1976	126	403	15	90	87	236	53	195	50	203	37	88
	1986	161	492	37	142	103	298	74	231	54	244	37	113
Other	1970	13	15	10	1	10	14	0	0	4	5	4	4
	1976	23	25	1	2	16	18	0	0	11	14	10	10
	1986	34	47	1	4	14	21	0	0	18	28	18	19
Not classified	1970	139	182	79	96	79	104	15	30	25	40	11	15
	1976	95	139	42	77	53	72	5	17	20	33	7	12
	1986	31	68	18	45	11	27	1	6	9	14	3	4

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

Science & Engineering Indicators—1989

Appendix table 2-2. S/E degrees, by institutional type and degree level: 1986

	Associate		Bachelor's		First professional		Master's		Doctorate	
Carnegie category	Institutions	Degrees	Institutions	Degrees	Institutions	Degrees	Institutions	Degrees	Institutions	Degrees
	Number									
Total	1,179	118,198	1,419	395,394	201	31,051	685	78,853	307	19,360
Doctorate	50	7,774	205	208,971	103	17,685	210	56,391	205	18,322
Comprehensive	160	8,841	556	133,952	21	1,625	339	17,931	38	224
Liberal arts	87	1,745	526	36,144	2	149	55	1,089	6	29
2-year	826	90,513	4	279	0	0	0	0	0	0
Specialized	37	4,462	103	12,435	74	11,568	54	2,173	37	352
Other	1	131	14	2,462	0	0	18	1,003	18	362
Not classified	18	4,732	11	1,151	1	24	9	266	3	71

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

Science & Engineering Indicators—1989

Appendix table 2-3. S/E degrees by Carnegie category, degree level, and field: 1986

Field and Carnegie category	Associate	Bachelor's	Master's	Doctorate
	Number			
Total science and engineering	71,734	375,770	78,245	19,350
Doctorate	4,208	202,333	56,085	18,312
Comprehensive	6,246	125,206	17,629	224
Liberal arts	1,604	35,828	1,089	29
2-year	54,902	146	0	0
Specialized	1,574	9,240	2,173	352
Other	3,200	3,017	1,269	433
Total sciences	66,354	298,709	56,931	15,907
Doctorate	4,195	146,244	38,399	14,940
Comprehensive	6,152	109,148	15,125	182
Liberal arts	1,595	34,641	1,048	28
2-year	51,365	17	0	0
Specialized	1,556	7,071	1,631	334
Other	1,491	1,588	728	423
Total physical sciences	1,019	15,786	3,676	3,104
Doctorate	35	7,390	2,976	3,056
Comprehensive	25	5,399	603	32
Liberal arts	18	2,632	29	7
2-year	854	0	0	0
Specialized	0	88	39	6
Other	87	277	29	3
Total environmental sciences	38	6,076	2,234	449
Doctorate	0	3,501	1,882	441
Comprehensive	1	1,987	269	6
Liberal arts	0	459	5	0
2-year	37	0	0	0
Specialized	0	20	37	1
Other	0	109	41	1
Math and computer sciences	11,567	58,583	11,241	1,086
Doctorate	508	24,809	7,403	1,079
Comprehensive	798	25,868	3,267	6
Liberal arts	214	4,598	105	1
2-year	7,872	15	0	0
Specialized	1,300	2,562	395	0
Other	875	731	71	0
Total life sciences	52,055	108,285	24,291	5,576
Doctorate	3,608	53,374	16,999	5,246
Comprehensive	5,263	39,574	5,926	57
Liberal arts	1,325	10,904	212	6
2-year	41,081	2	0	0
Specialized	250	4,338	1,126	267
Other	528	93	28	0
Total psychology	939	40,937	8,363	3,096
Doctorate	8	18,503	3,219	2,534
Comprehensive	34	16,505	3,933	74
Liberal arts	14	5,735	621	9
2-year	877	0	0	0
Specialized	5	61	34	60
Other	1	133	556	419
Total social sciences	736	69,042	7,126	2,596
Doctorate	36	38,667	5,920	2,584
Comprehensive	31	19,815	1,127	7
Liberal arts	24	10,313	76	5
2-year	644	0	0	0
Specialized	1	2	0	0
Other	0	245	3	0

(continued)

Appendix table 2-3. (Continued)

Field and Carnegie category	Associate	Bachelor's	Master's	Doctorate
	Number			
Total engineering	5,380	77,061	21,314	3,443
Doctorate	13	56,089	17,686	3,372
Comprehensive	94	16,058	2,504	42
Liberal arts	9	1,187	41	1
2-year	3,537	129	0	0
Specialized	18	2,169	542	18
Other	1,709	1,429	541	10

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

See figure 2-1.

Science & Engineering Indicators—1989

Appendix table 2-4. U.S. population and college enrollment[1] of 18- to 21-year-olds, by selected race and gender: 1970-88

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total male population	6,882	7,080	7,350	7,584	7,729	7,823	7,886	7,941	7,922	8,052	7,917	7,796	7,554	7,260	7,068	6,983	7,016
Total male enrollment	2,536	2,423	2,468	2,682	2,600	2,676	2,593	2,533	2,615	2,689	2,722	2,650	2,710	2,662	2,556	2,833	2,660
Percent	36.8	34.2	33.6	35.4	33.6	34.2	32.9	31.9	33.0	33.4	34.4	34.0	35.9	36.7	36.2	40.6	37.9
Total female population	7,535	7,683	7,943	8,109	8,230	8,318	8,359	8,373	8,350	8,428	8,276	8,062	7,833	7,623	7,385	7,273	7,252
Total female enrollment	2,260	2,178	2,321	2,575	2,735	2,668	2,603	2,664	2,743	2,899	2,896	2,785	2,754	2,862	2,726	2,854	3,068
Percent	30.0	28.3	29.2	31.8	33.2	32.1	31.1	31.8	32.9	34.4	35.0	34.5	35.2	37.5	36.9	39.2	42.3
White male population	5,973	6,129	6,373	6,545	6,651	6,730	6,783	6,827	6,793	6,820	6,626	6,501	6,289	6,069	5,850	5,757	5,765
White male enrollment	2,304	2,194	2,210	2,417	2,317	2,396	2,275	2,250	2,346	2,363	2,377	2,346	2,367	2,313	2,216	2,416	2,308
Percent	38.6	35.8	34.7	36.9	34.8	35.6	33.5	33.0	34.5	34.6	35.9	36.1	37.6	38.1	37.9	42.0	40.0
White female population	6,481	6,573	6,784	6,903	6,991	7,051	7,073	7,072	7,033	7,051	6,895	6,689	6,461	6,280	6,065	5,951	5,955
White female enrollment	2,024	1,952	2,039	2,238	2,368	2,282	2,251	2,327	2,363	2,514	2,519	2,412	2,380	2,483	2,295	2,401	2,601
Percent	31.2	29.7	30.1	32.4	33.9	32.4	31.8	32.9	33.6	35.7	36.5	36.1	36.8	39.5	37.8	40.3	43.7
Black male population	825	854	865	941	957	946	951	956	967	1,032	1,058	1,059	1,040	1,017	985	964	962
Black male enrollment	193	189	202	218	234	205	220	220	199	225	216	205	241	261	227	278	198
Percent	23.4	22.1	23.4	23.2	24.5	21.7	23.1	23.0	20.6	21.8	20.4	19.4	23.2	25.7	23.0	28.8	20.6
Black female population	980	998	1,031	1,085	1,110	1,130	1,132	1,137	1,148	1,193	1,194	1,177	1,167	1,132	1,107	1,085	1,079
Black female enrollment	204	168	222	280	320	326	288	283	309	312	300	295	298	272	318	326	356
Percent	20.8	16.8	21.5	25.8	28.8	28.8	25.4	24.9	26.9	26.2	25.1	25.1	25.5	24.0	28.7	30.0	33.0
Hispanic male population	372	355	428	416	458	462	439	486	589	611	559	577	508	551	716	710	762
Hispanic male enrollment	83	76	99	105	108	99	83	110	120	125	99	102	105	97	151	176	151
Percent	22.3	21.4	23.1	25.2	23.6	21.4	18.9	22.6	20.4	20.5	17.7	17.7	20.7	17.6	21.1	24.8	19.8
Hispanic female population	419	382	466	484	507	519	521	525	578	642	561	610	579	594	658	662	719
Hispanic female enrollment	68	77	107	114	119	120	94	110	110	127	148	157	164	157	155	132	164
Percent	16.2	20.2	23.0	23.6	23.5	23.1	18.0	21.0	19.0	19.8	26.4	25.7	28.3	26.4	23.6	19.9	22.8

[1] In thousands.

SOURCES: U.S. Bureau of the Census, *Current Population Report*, Series P-20 (Washington, DC: U.S. Bureau of the Census), various issues; and unpublished tabulations.

See figure 2-2.

Science & Engineering Indicators—1989

Appendix table 2-5. Undergraduate enrollment in engineering and engineering technology programs: 1979-88

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
	Engineering programs									
Total full-time	340,488	365,117	387,577	403,390	406,144	394,635	384,191	369,520	356,998	346,169
Freshman	103,724	110,149	115,280	115,303	109,638	105,249	103,225	99,238	95,453	98,009
Sophomore	78,594	84,982	87,519	89,785	89,515	83,946	79,627	76,195	73,317	71,030
Junior	74,928	80,024	86,633	90,541	91,233	89,509	84,875	80,386	77,085	73,761
Senior	77,823	84,442	92,414	102,055	109,036	109,695	110,305	107,773	104,003	97,614
Fifth year	5,419	5,520	5,731	5,706	6,722	6,236	6,159	5,928	7,140	5,755
Total part-time	25,811	32,227	32,825	31,940	35,061	34,864	36,673	38,137	35,200	39,243
Number of schools (total)	286	287	286	286	292	289	297	311	316	320
ABET-accredited schools[1]	239	246	250	249	258	258	264	270	277	281
	Engineering technology programs									
Total full-time	NA	NA	134,444	120,342	112,745	111,446	83,038	90,536	80,600	79,624
First year	NA	NA	65,893	59,339	53,032	46,806	34,389	39,177	32,685	33,477
Second year	NA	NA	40,774	36,807	33,799	31,716	23,293	25,612	22,906	21,852
Other full-time associates	NA	NA	872	797	925	1,165	466	657	1,404	1,760
Bachelor of engineering technology Third and later years	NA	NA	26,905	23,399	24,989	31,759	24,890	25,090	23,605	22,535
Total part-time	NA	NA	56,708	55,791	50,481	46,451	40,533	46,854	47,901	52,080
Number of schools	NA	NA	NA	NA	NA	NA	200	257	291	310

NA = Not available.

[1] Schools with at least one curriculum accredited by the Accreditation Board of Engineering and Technology (ABET).

SOURCE: American Association of Engineering Societies, Engineering Manpower Commission, *Engineering & Technology Enrollments, Fall 1988*, Parts I and II (Washington, DC: American Association of Engineering Societies, 1988).

See figure 2-3.

Science & Engineering Indicators—1989

Appendix table 2-6. College major choices of Merit Scholars: 1982-88

	1982	1983	1984	1985	1986	1987	1988
Engineering							
Male	969	1,068	1,039	1,112	1,142	1,030	997
Female	336	361	363	288	247	251	245
Science							
Male	973	986	1,121	1,127	1,060	1,002	979
Female	544	656	603	578	483	478	476
Astronomy							
Male	19	14	20	17	22	28	28
Female	10	2	9	7	10	5	5
Biochemistry							
Male	65	62	70	69	61	80	79
Female	56	65	77	72	45	63	53
Biosciences, unspecified							
Male	85	72	85	113	107	69	84
Female	103	122	131	121	115	79	95
Biology, botany, zoology							
Male	61	42	47	46	56	75	73
Female	71	96	70	88	80	88	91
Biophysics							
Male	4	8	12	13	5	10	5
Female	5	5	4	3	1	2	1
Chemistry							
Male	77	64	87	98	87	71	91
Female	47	64	48	60	48	45	37
Computer science							
Male	244	325	326	264	219	186	180
Female	104	135	92	49	26	29	29
Earth sciences							
Male	22	16	10	13	10	9	5
Female	12	16	8	12	5	7	9
Math and statistics							
Male	118	103	139	145	154	142	104
Female	65	63	91	74	73	69	68
Physical sciences, unspecified							
Male	66	65	71	84	74	74	107
Female	33	29	37	36	29	43	49
Physics							
Male	212	215	254	265	265	258	223
Female	38	59	36	56	51	48	39
Health sciences							
Male	357	344	359	386	384	312	249
Female	325	315	307	300	274	234	236
Humanities and social sciences							
Male	581	574	626	706	809	775	758
Female	544	590	642	695	710	717	757
Business							
Male	135	100	114	157	170	171	183
Female	138	135	139	135	147	116	136
Arts							
Male	72	52	70	80	70	65	70
Female	78	72	78	71	80	76	76
Other							
Male	114	95	92	91	118	141	163
Female	140	110	130	135	148	155	161
Undecided							
Male	75	57	82	82	102	306	439
Female	67	51	93	78	82	298	285

SOURCE: National Merit Scholarship Corporation, 1982-88, *Annual Report* (Evanston, IL: National Merit Scholarship Corporation) ongoing annual series. Used with permission.

See figure 2-6.

Appendix table 2-7. S/E graduate students in doctorate-granting institutions, by gender: 1980-88

Field	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	297,264	302,390	309,547	317,865	320,506	328,256	339,349	343,228	347,533
Male	210,795	211,364	214,477	219,658	221,174	226,050	233,369	234,481	234,722
Female	86,469	91,026	95,070	98,207	99,332	102,206	105,980	108,747	112,811
Total science	227,121	228,017	231,369	232,541	233,391	238,017	242,555	246,226	250,555
Male	146,789	144,322	144,617	143,611	143,819	146,250	148,279	149,535	150,158
Female	80,332	83,695	86,752	88,930	89,572	91,767	94,276	96,691	100,397
Physical sciences	25,393	25,780	26,499	27,747	28,410	29,312	30,543	30,967	31,266
Male	21,176	21,225	21,579	22,366	22,736	23,318	24,199	24,374	24,308
Female	4,217	4,555	4,920	5,381	5,674	5,994	6,344	6,593	6,958
Environmental sciences	12,795	13,063	13,757	14,281	14,286	14,217	13,989	13,368	12,967
Male	9,890	9,964	10,356	10,671	10,740	10,601	10,344	9,878	9,473
Female	2,905	3,099	3,401	3,610	3,546	3,616	3,645	3,490	3,494
Mathematical sciences	13,625	14,004	14,758	14,885	15,067	15,268	15,663	16,221	16,795
Male	10,168	10,274	10,650	10,655	10,833	10,823	11,072	11,446	11,870
Female	3,457	3,730	4,108	4,230	4,234	4,445	4,591	4,775	4,925
Computer science	11,384	13,141	15,576	18,306	20,366	23,823	25,204	26,083	26,950
Male	8,899	9,906	11,442	13,325	15,065	17,934	19,272	19,867	20,336
Female	2,485	3,235	4,134	4,981	5,301	5,889	5,932	6,216	6,614
Life sciences[1]	54,325	53,330	53,454	53,147	53,290	53,170	54,044	53,987	55,032
Male	35,309	34,217	33,428	32,901	32,824	32,389	32,626	32,422	32,472
Female	19,016	19,113	20,026	20,246	20,466	20,781	21,418	21,565	22,560
Psychology	29,384	29,052	29,082	30,011	30,126	30,581	30,739	31,584	32,680
Male	14,218	13,494	12,960	12,999	12,667	12,307	12,018	12,056	12,215
Female	15,166	15,558	16,122	17,012	17,459	18,274	18,721	19,528	20,465
Social sciences	80,285	79,647	78,243	74,164	71,846	71,646	72,373	74,016	74,865
Male	47,129	45,242	44,202	40,694	38,954	38,878	38,748	39,492	39,484
Female	33,156	34,405	34,041	33,470	32,892	32,768	33,625	34,524	35,381
Total engineering	70,143	74,373	78,178	85,324	87,115	90,239	96,794	97,002	96,978
Male	64,006	67,042	69,860	76,047	77,355	79,800	85,090	84,946	84,564
Female	6,137	7,331	8,318	9,277	9,760	10,439	11,704	12,056	12,414

[1] Includes biological and agricultural sciences and excludes health fields.

SOURCE: NSF, Division of Science Resources Studies.

See figure O-15 in Overview.

Science & Engineering Indicators—1989

Appendix table 2-8. S/E graduate enrollment in doctorate-granting institutions, by field, citizenship, and racial/ethnic background: 1980-88

Field, citizenship, and racial/ethnic background	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	297,264	302,390	309,547	317,865	320,506	328,256	338,349	343,228	347,533
Total U.S. citizens	NA	NA	248,448	251,283	251,975	255,329	258,413	258,491	258,396
Black, non-Hispanic	8,033	7,832	8,997	9,241	8,883	8,769	8,870	8,765	9,395
Asian/Pacific Islander	6,555	6,219	7,168	7,927	8,746	10,526	11,355	12,867	14,020
Hispanic	5,662	5,776	7,211	7,931	7,897	7,928	8,250	8,446	8,438
White, non-Hispanic	178,508	170,576	198,190	207,211	205,612	206,818	211,184	211,589	212,028
Other or unknown	647	540	26,882	18,973	20,837	21,288	18,854	16,824	14,515
Foreign	NA	NA	61,099	66,582	68,531	72,927	79,936	84,737	89,137
Total science	227,121	228,017	231,369	232,541	233,391	238,017	242,555	246,226	250,555
Total U.S. citizens	NA	NA	194,320	192,362	191,614	192,790	193,427	193,754	195,075
Black, non-Hispanic	7,199	7,051	8,013	8,038	7,588	7,539	7,561	7,486	8,065
Asian/Pacific Islander	4,054	4,207	4,759	5,094	5,468	6,246	6,708	7,685	8,356
Hispanic	4,672	4,907	6,217	6,622	6,521	6,588	6,712	6,850	6,850
White, non-Hispanic	143,144	135,272	158,150	161,928	159,546	159,808	161,523	161,313	163,116
Other or unknown	572	432	17,181	10,680	12,491	12,609	11,023	10,420	8,688
Foreign	NA	NA	37,049	40,179	41,777	45,227	49,128	52,472	55,480
Physical sciences	25,393	25,780	26,499	27,747	28,410	29,312	30,543	30,967	31,266
Total U.S. citizens	NA	NA	19,860	20,375	20,618	20,690	20,826	20,687	20,562
Black, non-Hispanic	332	345	434	427	456	388	383	398	437
Asian/Pacific Islander	576	565	628	641	787	837	822	936	1,139
Hispanic	337	355	461	539	507	564	587	547	574
White, non-Hispanic	15,562	15,164	16,734	17,641	17,631	17,369	17,654	17,186	17,382
Other or unknown	14	16	1,603	1,127	1,237	1,532	1,380	1,620	1,030
Foreign	NA	NA	6,639	7,372	7,792	8,622	9,717	10,280	10,704
Environmental sciences	12,795	13,063	13,757	14,281	14,286	14,217	13,989	13,368	12,967
Total U.S. citizens	NA	NA	11,943	12,479	12,550	12,403	12,024	11,262	10,627
Black, non-Hispanic	72	79	75	99	101	111	90	87	97
Asian/Pacific Islander	153	115	178	206	155	167	146	174	189
Hispanic	133	146	156	200	241	192	217	227	211
White, non-Hispanic	8,957	9,510	10,382	11,350	10,952	10,899	10,855	10,230	9,755
Other or unknown	36	14	1,152	624	1,101	1,034	716	544	375
Foreign	NA	NA	1,814	1,802	1,736	1,814	1,965	2,106	2,340
Mathematical sciences	13,625	14,004	14,758	14,885	15,067	15,268	15,663	16,221	16,795
Total U.S. citizens	NA	NA	10,531	10,270	10,176	10,177	10,178	10,418	10,715
Black, non-Hispanic	220	239	268	275	255	267	303	312	293
Asian/Pacific Islander	292	320	404	426	421	498	586	645	611
Hispanic	156	203	244	295	250	231	240	237	296
White, non-Hispanic	7,342	7,163	8,513	8,585	8,419	8,336	8,192	8,317	8,735
Other or unknown	38	6	1,102	689	831	845	857	907	780
Foreign	NA	NA	4,227	4,615	4,891	5,091	5,485	5,803	6,080
Computer science	11,384	13,141	15,576	18,306	20,366	23,823	25,204	26,083	26,950
Total U.S. citizens	NA	NA	11,954	13,552	14,830	17,391	18,303	18,546	19,071
Black, non-Hispanic	117	189	349	371	377	457	506	591	641
Asian/Pacific Islander	395	505	645	808	890	1,376	1,526	1,837	2,072
Hispanic	68	78	176	194	208	381	347	436	407
White, non-Hispanic	5,603	6,411	9,225	10,202	10,889	12,689	13,543	14,108	14,680
Other or unknown	8	3	1,559	1,977	2,466	2,488	2,381	1,574	1,271
Foreign	NA	NA	3,622	4,754	5,536	6,432	6,901	7,537	7,879

(continued)

Appendix table 2-8. (Continued)

Field, citizenship, and racial/ethnic background	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Life sciences[2]	54,255	53,330	53,454	53,147	53,290	53,170	54,044	53,987	55,032
Total U.S. citizens	NA	NA	45,643	44,776	44,711	43,971	43,769	42,680	42,738
Black, non-Hispanic	802	767	950	932	952	984	947	925	1,051
Asian/Pacific Islander	1,162	993	1,170	1,272	1,348	1,463	1,613	1,747	1,988
Hispanic	942	638	875	968	987	1,122	1,146	1,138	1,260
White, non-Hispanic	38,038	36,079	39,722	40,005	40,253	38,763	38,584	37,321	37,251
Other or unknown	72	45	641	352	192	348	273	191	271
Foreign	NA	NA	7,811	8,371	8,579	9,199	10,275	11,307	12,294
Psychology	29,384	29,052	29,082	30,011	30,126	30,581	30,739	31,584	32,680
Total U.S. citizens	NA	NA	27,975	28,822	28,923	29,292	29,443	30,251	31,227
Black, non-Hispanic	1,024	1,051	1,131	1,286	1,317	1,195	1,200	1,203	1,278
Asian/Pacific Islander	288	334	352	382	410	438	488	602	628
Hispanic	1,045	1,058	1,240	1,278	1,360	1,380	1,459	1,371	1,426
White, non-Hispanic	18,997	17,053	21,935	24,296	23,720	24,178	24,628	25,731	26,425
Other or unknown	181	61	3,317	1,580	2,116	2,101	1,668	1,344	1,470
Foreign	NA	NA	1,107	1,189	1,203	1,289	1,296	1,333	1,453
Social sciences	80,285	79,647	78,243	74,164	71,846	71,646	72,373	74,016	74,865
Total U.S. citizens	NA	NA	66,414	62,088	59,806	58,866	58,884	59,910	60,135
Black, non-Hispanic	4,632	4,381	4,806	4,648	4,130	4,137	4,032	3,970	4,268
Asian/Pacific Islander	1,188	1,375	1,382	1,359	1,457	1,467	1,527	1,744	1,729
Hispanic	1,991	2,434	3,065	3,148	2,968	2,718	2,716	2,894	2,676
White, non-Hispanic	48,645	44,892	51,639	49,849	47,682	47,574	48,067	48,420	48,888
Other or unknown	223	287	5,522	3,084	3,569	2,970	2,542	2,882	2,574
Foreign	NA	NA	11,829	12,076	12,040	12,780	13,489	14,106	14,730
Engineering	70,143	74,373	78,178	85,324	87,115	90,239	95,794	97,002	96,978
Total U.S. citizens	NA	NA	54,128	58,921	60,361	62,539	64,986	64,737	63,321
Black, non-Hispanic	834	781	984	1,203	1,295	1,230	1,309	1,279	1,330
Asian/Pacific Islander	2,501	2,012	2,409	2,833	3,278	4,280	4,647	5,182	5,664
Hispanic	990	869	994	1,309	1,376	1,340	1,538	1,596	1,588
White, non-Hispanic	35,364	35,304	40,040	45,283	46,066	47,010	49,661	50,276	48,912
Other or unknown	75	108	9,701	8,293	8,346	8,679	7,831	6,404	5,827
Foreign	NA	NA	24,050	26,403	26,754	27,700	30,808	32,265	33,657

NA = Not available.

[1] For part-time students, distribution by citizenship was not requested prior to 1982.

[2] Includes agricultural and biological sciences and excludes health fields.

SOURCE: NSF, Division of Science Resources Studies.

See text table 2-2.

Science & Engineering Indicators—1989

Appendix table 2-9. S/E graduate enrollment in doctorate-granting institutions, by field, racial/ethnic group, citizenship, and enrollment status: 1980-88

Field, racial/ethnic group, and citizenship	Full-time								
	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	208,232	212,083	216,012	223,135	224,701	227,486	236,748	240,966	245,463
Total U.S. citizens	161,547	161,566	162,868	165,673	165,736	163,977	166,651	167,312	167,741
White	124,732	118,478	132,383	139,962	139,116	135,971	139,563	138,582	139,345
Black	4,884	4,798	5,329	5,379	5,227	5,181	5,196	5,224	5,638
Hispanic	3,965	3,793	4,514	4,942	4,996	5,836	5,400	5,499	5,538
Asian	4,536	4,135	4,654	5,308	6,051	6,930	7,623	8,710	9,663
Other U.S. citizens	23,430	30,362	15,988	10,082	10,346	10,059	8,869	9,297	7,557
Foreign	46,691	50,517	53,144	57,462	58,965	63,509	70,097	73,654	77,722
Total sciences	166,293	167,266	167,325	170,445	170,727	172,669	177,717	180,614	183,807
Total U.S. citizens	137,111	135,950	134,993	135,222	134,369	132,658	134,028	134,351	134,516
White	106,391	100,439	111,231	116,040	114,419	111,774	113,859	113,080	113,664
Black	4,448	4,404	4,856	4,772	4,585	4,536	4,484	4,560	4,903
Hispanic	3,403	3,314	3,944	4,209	4,289	5,118	4,567	4,678	4,618
Asian	3,052	3,067	3,332	3,706	4,024	4,466	4,918	5,656	6,157
Other U.S. citizens	19,817	24,726	11,630	6,495	7,052	6,764	6,200	6,377	5,174
Foreign	29,188	31,316	32,332	35,223	36,358	40,011	43,689	46,263	49,291
Physical sciences	22,254	22,600	23,330	24,502	25,147	25,938	27,069	27,652	27,832
Total U.S. citizens	16,668	16,523	17,038	17,458	17,719	17,685	17,778	17,856	17,621
White	13,638	13,260	14,415	15,145	15,118	14,912	15,072	14,780	14,831
Black	262	274	339	330	363	300	312	327	354
Hispanic	288	315	375	434	444	514	531	495	525
Asian	495	452	502	538	683	742	737	859	1,027
Other U.S. citizens	1,985	2,222	1,407	1,011	1,111	1,217	1,126	1,395	884
Foreign	5,586	6,077	6,292	7,044	7,428	8,253	9,291	9,796	10,211
Environmental sciences	10,265	10,491	10,873	11,497	11,266	10,871	10,862	10,097	9,893
Total U.S. citizens	8,930	9,026	9,269	9,842	9,716	9,236	9,080	8,217	7,791
White	7,170	6,849	7,999	8,920	8,391	8,067	8,155	7,395	7,113
Black	54	59	59	77	79	82	62	63	70
Hispanic	111	125	112	135	183	160	181	193	171
Asian	135	100	130	144	132	147	137	154	174
Other U.S. citizens	1,460	1,893	969	566	931	780	545	412	263
Foreign	1,335	1,465	1,604	1,655	1,550	1,635	1,782	1,880	2,102
Mathematical sciences	9,368	9,680	10,174	10,316	10,613	11,160	11,727	12,364	12,791
Total U.S. citizens	6,213	6,159	6,453	6,236	6,266	6,509	6,776	7,071	7,254
White	4,852	4,599	5,227	5,224	5,226	5,318	5,562	5,632	5,997
Black	106	119	146	128	134	162	192	212	175
Hispanic	125	157	163	201	168	161	160	186	215
Asian	197	231	278	285	246	352	423	454	419
Other U.S. citizens	933	1,053	639	398	492	516	439	587	448
Foreign	3,155	3,521	3,721	4,080	4,347	4,651	4,951	5,293	5,537
Computer science	5,900	6,465	7,908	9,276	10,108	12,374	13,389	13,639	13,811
Total U.S. citizens	4,030	4,260	5,137	5,763	6,109	7,481	7,943	7,929	7,729
White	2,513	3,161	3,850	4,419	4,736	5,509	6,084	6,044	5,893
Black	38	70	116	118	128	154	227	245	244
Hispanic	30	37	86	83	97	106	138	129	140
Asian	142	199	279	445	453	597	720	883	1,005
Other U.S. citizens	1,307	793	806	698	695	1,115	774	628	447
Foreign	1,870	2,205	2,771	3,513	3,999	4,893	5,446	5,710	6,082
Life sciences[2]	45,408	45,084	44,726	44,654	45,011	44,417	45,461	45,834	46,912
Total U.S. citizens	38,909	38,156	37,574	36,935	37,084	35,928	35,932	35,376	35,468
White	32,088	30,565	32,884	33,215	33,553	31,792	31,895	31,106	30,910
Black	635	599	736	733	697	727	705	715	803
Hispanic	787	531	726	804	827	1,701	959	971	1,080
Asian	1,008	866	989	1,092	1,201	1,297	1,421	1,552	1,766
Other U.S. citizens	4,391	5,595	2,239	1,091	806	411	952	1,032	909
Foreign	6,505	6,928	7,152	7,719	7,927	8,489	9,529	10,458	11,444

(continued)

Appendix table 2-9. (Continued)

Field, racial/ethnic group, and citizenship	Full-time								
	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Psychology	21,580	21,544	21,103	22,150	21,601	21,341	21,997	22,567	23,360
Total U.S. citizens	20,526	20,712	20,216	21,214	20,677	20,309	20,966	21,478	22,149
White	14,764	13,062	15,574	18,041	17,277	17,097	17,702	18,477	18,911
Black	830	788	802	875	864	813	831	815	881
Hispanic	846	871	936	908	938	915	1,035	971	977
Asian	247	291	274	298	321	337	385	493	510
Other U.S. citizens	3,839	5,700	2,630	1,092	1,277	1,147	1,013	722	870
Foreign	1,054	832	887	936	924	1,032	1,031	1,089	1,211
Social sciences	51,518	51,402	49,211	48,050	46,981	46,568	47,212	48,461	49,208
Total U.S. citizens	41,835	41,114	39,306	37,774	36,798	35,510	35,553	36,424	36,504
White	31,366	28,943	31,282	31,076	30,118	29,079	29,389	29,646	30,009
Black	2,523	2,495	2,658	2,511	2,320	2,298	2,155	2,183	2,376
Hispanic	1,216	1,278	1,546	1,644	1,632	1,561	1,563	1,733	1,510
Asian	828	928	880	904	988	994	1,095	1,261	1,256
Other U.S. citizens	5,902	7,470	2,940	1,639	1,740	1,578	1,351	1,601	1,353
Foreign	9,683	10,288	9,905	10,276	10,183	11,058	11,659	12,037	12,704
Total engineering	41,939	44,817	48,687	52,690	53,974	54,817	59,031	60,352	61,656
Total U.S. citizens	24,436	25,616	27,875	30,451	31,367	31,319	32,623	32,961	33,225
White	18,341	18,039	21,152	23,922	24,697	24,197	25,704	25,502	25,681
Black	436	394	473	607	642	645	712	664	735
Hispanic	562	479	570	733	707	718	833	821	920
Asian	1,484	1,068	1,322	1,602	2,027	2,464	2,705	3,054	3,506
Other U.S. citizens	3,613	5,636	4,358	3,587	3,294	3,295	2,669	2,920	2,383
Foreign	17,503	19,201	20,812	22,239	22,607	23,498	26,408	27,391	28,431

(continued)

Appendix table 2-9. (Continued)

Field, racial/ethnic group, and citizenship	Part-time								
	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	89,032	90,307	93,535	94,730	95,805	100,770	101,601	102,262	102,070
Total U.S. citizens	NA	NA	85,580	85,610	86,239	91,352	91,762	91,179	90,655
White	53,776	52,098	65,807	67,249	66,496	70,847	71,621	73,007	72,683
Black	3,149	3,034	3,668	3,862	3,656	3,588	3,574	3,541	3,757
Hispanic	1,697	1,983	2,697	2,989	2,901	2,818	2,850	2,937	2,900
Asian	2,019	2,084	2,514	2,619	2,695	3,596	3,732	4,157	4,357
Other U.S. citizens	NA	NA	10,894	8,891	10,491	10,503	9,985	7,537	6,958
Foreign	NA	NA	7,955	9,120	9,566	9,418	9,839	11,083	11,415
Total sciences	60,828	60,751	64,044	62,096	62,664	65,348	64,838	65,612	66,748
Total U.S. citizens	NA	NA	59,327	57,140	57,245	60,132	59,399	59,403	60,559
White	36,753	34,833	46,919	45,888	45,127	48,034	47,664	48,233	49,452
Black	2,751	2,647	3,157	3,266	3,003	3,003	2,977	2,926	3,162
Hispanic	1,269	1,593	2,273	2,413	2,232	2,196	2,145	2,162	2,232
Asian	1,002	1,140	1,427	1,388	1,444	1,780	1,790	2,029	2,199
Other U.S. citizens	NA	NA	5,551	4,185	5,439	5,119	4,823	4,053	3,514
Foreign	NA	NA	4,717	4,956	5,419	5,216	5,439	6,209	6,189
Physical sciences	3,139	3,180	3,169	3,245	3,263	3,374	3,474	3,315	3,434
Total U.S. citizens	NA	NA	2,822	2,917	2,899	3,005	3,048	2,831	2,941
White	1,924	1,904	2,319	2,496	2,513	2,457	2,582	2,406	2,551
Black	70	71	95	97	93	88	71	71	83
Hispanic	49	40	86	105	63	50	56	52	49
Asian	81	113	126	103	104	95	85	77	112
Other U.S. citizens	NA	NA	196	116	126	315	254	225	146
Foreign	NA	NA	347	328	364	369	426	484	493
Environmental sciences	2,530	2,572	2,884	2,784	3,020	3,346	3,127	3,271	3,074
Total U.S. citizens	NA	NA	2,674	2,637	2,834	3,167	2,944	3,045	2,836
White	1,787	1,661	2,383	2,430	2,561	2,832	2,700	2,835	2,642
Black	18	20	16	22	22	29	28	24	27
Hispanic	22	21	44	65	58	32	36	34	40
Asian	18	15	48	62	23	20	9	20	15
Other U.S. citizens	NA	NA	183	58	170	254	171	132	112
Foreign	NA	NA	210	147	186	179	183	226	238
Mathematical sciences	4,257	4,324	4,584	4,569	4,454	4,108	3,936	3,857	4,004
Total U.S. citizens	NA	NA	4,078	4,034	3,910	3,668	3,402	3,347	3,461
White	2,490	2,564	3,286	3,361	3,193	3,018	2,630	2,685	2,738
Black	114	120	122	147	121	105	111	100	118
Hispanic	31	46	81	94	82	70	80	51	81
Asian	95	89	126	141	175	146	163	191	192
Other U.S. citizens	NA	NA	463	291	339	329	418	320	332
Foreign	NA	NA	506	535	544	440	534	510	543
Computer science	5,484	6,676	7,668	9,030	10,258	11,449	11,815	12,444	13,139
Total U.S. citizens	NA	NA	6,817	7,789	8,721	9,910	10,360	10,617	11,342
White	3,090	3,250	5,375	5,783	6,153	7,180	7,459	8,064	8,787
Black	79	119	233	253	249	303	279	346	397
Hispanic	38	36	90	111	111	275	209	297	267
Asian	253	306	366	363	437	779	806	954	1,067
Other U.S. citizens	NA	NA	753	1,279	1,771	1,373	1,607	956	824
Foreign	NA	NA	851	1,241	1,537	1,539	1,455	1,827	1,797
Life sciences[2]	8,847	8,246	8,728	8,493	8,279	8,753	8,583	8,153	8,120
Total U.S. citizens	NA	NA	8,069	7,841	7,627	8,043	7,837	7,304	7,270
White	5,950	5,514	6,838	6,790	6,700	6,971	6,689	6,215	6,341
Black	167	168	214	199	255	257	242	210	248
Hispanic	155	107	149	164	160	147	187	167	180
Asian	154	127	181	180	147	166	192	195	222
Other U.S. citizens	NA	NA	687	508	365	502	527	517	279
Foreign	NA	NA	659	652	652	710	746	849	850

(continued)

Appendix table 2-9. (Continued)

Field, racial/ethnic group, and citizenship	Part-time								
	1980[1]	1981[1]	1982	1983	1984	1985	1986	1987	1988
Psychology	7,804	7,508	7,979	7,861	8,525	9,240	8,742	9,017	9,320
Total U.S. citizens	NA	NA	7,759	7,608	8,246	8,983	8,477	8,773	9,078
White	4,233	3,991	6,361	6,255	6,443	7,081	6,926	7,254	7,514
Black	194	263	329	411	453	382	369	388	397
Hispanic	199	187	304	370	422	465	424	400	449
Asian	41	43	78	84	89	101	103	109	118
Other U.S. citizens	NA	NA	687	488	839	954	655	622	600
Foreign	NA	NA	220	253	279	257	265	244	242
Social sciences	28,767	28,245	29,032	26,114	24,865	25,078	25,161	25,555	25,657
Total U.S. citizens	NA	NA	27,108	24,314	23,008	23,356	23,331	23,486	23,631
White	17,279	15,949	20,357	18,773	17,564	18,495	18,678	18,774	18,879
Black	2,109	1,886	2,148	2,137	1,810	1,839	1,877	1,787	1,892
Hispanic	775	1,156	1,519	1,504	1,336	1,157	1,153	1,161	1,166
Asian	360	447	502	455	469	473	432	483	473
Other U.S. citizens	NA	NA	2,582	1,445	1,829	1,392	1,191	1,281	1,221
Foreign	NA	NA	1,924	1,800	1,857	1,722	1,830	2,069	2,026
Total engineering	28,204	29,556	29,491	32,634	33,141	35,422	36,763	36,650	35,322
Total U.S. citizens	NA	NA	26,253	28,470	28,994	31,220	32,363	31,776	30,096
White	17,023	17,265	18,888	21,361	21,369	22,813	23,957	24,774	23,231
Black	398	387	511	596	653	585	597	615	595
Hispanic	428	390	424	576	669	622	705	775	668
Asian	1,017	944	1,087	1,231	1,251	1,816	1,942	2,128	2,158
Other U.S. citizens	NA	NA	5,343	4,706	5,052	5,384	5,162	3,484	3,444
Foreign	NA	NA	3,238	4,164	4,147	4,202	4,400	4,874	5,226

NA = Not available.

[1] For part-time students, distribution by citizenship was not requested prior to 1982.

[2] Includes agricultural and biological sciences and excludes health fields.

SOURCE: NSF, Division of Science Resources Studies.

See text table 2-2 and figure O-16 in Overview.

Appendix table 2-10. S/E postdoctorates in doctorate-granting institutions, by field and citizenship: 1980-88

Field	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total sciences and engineering	14,013	14,781	14,676	15,703	16,229	16,988	17,974	18,925	19,877
Foreign	5,409	5,938	5,962	6,210	6,516	7,220	7,824	8,514	9,318
Total sciences	13,035	13,741	13,698	14,602	15,035	15,641	16,576	17,483	18,201
Foreign	4,733	5,229	5,305	5,519	5,757	6,313	6,884	7,568	8,216
Total physical sciences	4,264	4,462	4,281	4,444	4,386	4,517	4,843	4,953	5,187
Foreign	2,159	2,358	2,367	2,385	2,412	2,501	2,640	2,778	2,931
Total environmental sciences	308	339	335	415	488	375	417	420	508
Foreign	102	126	121	159	164	125	141	162	189
Total mathematical sciences	162	113	194	170	203	226	201	228	280
Foreign	92	61	126	90	100	114	101	110	133
Total computer science	43	34	46	82	63	74	74	100	91
Foreign	13	16	12	45	21	29	29	35	39
Total life sciences[1]	7,345	7,990	8,035	8,699	9,116	9,583	10,169	10,934	11,309
Foreign	2,192	2,491	2,513	2,663	2,910	3,363	3,796	4,321	4,779
Total psychology	475	471	520	435	422	498	520	458	497
Foreign	30	54	65	61	46	54	50	73	73
Total social sciences	438	332	287	357	357	368	352	390	329
Foreign	145	123	101	116	104	127	127	89	72
Total engineering	978	1,040	978	1,101	1,194	1,347	1,398	1,442	1,676
Foreign	676	709	657	691	759	907	940	946	1,102

[1] Includes biological and agricultural sciences and excludes health fields.

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-7.

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Appendix table 2-11. Academic degrees, by degree level, S/E degrees, and S/E degrees earned by females: 1960-88

	Bachelor's					Master's					Doctorates				
	Number			Percent		Number			Percent		Number			Percent	
	Total	S/E	Female	S/E	Female[1]	Total	S/E	Female	S/E	Female[1]	Total	S/E	Female	S/E	Female[1]
1960	394,889	120,937	19,362	30.6	16.0	74,497	20,012	2,074	26.9	10.4	9,733	6,263	443	64.3	7.1
1961	401,784	121,660	20,595	30.3	16.9	78,269	22,786	2,464	29.1	10.8	10,413	6,721	494	64.5	7.4
1962	420,485	127,469	23,485	30.3	18.4	84,889	25,146	2,812	29.6	11.2	11,500	7,438	537	64.7	7.2
1963	450,592	135,964	27,099	30.2	19.9	91,418	27,367	3,194	29.9	11.7	12,728	8,219	598	64.6	7.3
1964	502,104	153,361	32,473	30.5	21.2	101,222	30,271	3,567	29.9	11.8	14,325	9,224	692	64.4	7.5
1965	538,930	164,936	36,213	30.6	22.0	112,195	33,835	4,082	30.2	12.1	16,340	10,476	744	64.1	7.1
1966	555,613	173,471	39,482	31.2	22.8	140,772	38,083	4,882	27.1	12.8	17,949	11,458	909	63.8	7.9
1967	594,862	187,849	44,002	31.6	23.4	157,892	41,800	5,717	26.5	13.7	20,403	12,982	1,086	63.6	8.4
1968	671,591	212,174	53,463	31.6	25.2	177,150	45,425	6,512	25.6	14.3	22,936	14,448	1,298	63.0	9.0
1969	769,683	244,519	63,196	31.8	25.8	194,414	48,425	7,314	24.9	15.1	25,743	16,039	1,483	62.3	9.2
1970	833,322	264,122	68,878	31.7	26.1	209,387	49,318	8,577	23.6	17.4	29,498	17,743	1,626	60.1	9.2
1971	884,386	271,176	72,996	30.7	26.9	231,486	50,624	8,658	21.9	17.1	31,867	18,949	1,941	59.5	10.2
1972	937,884	281,228	77,671	30.0	27.6	252,774	53,567	9,557	21.2	17.8	33,041	19,007	2,103	57.5	11.1
1973	980,707	295,391	83,839	30.1	28.4	264,525	54,234	9,760	20.5	18.0	33,755	19,001	2,450	56.3	12.9
1974	1,008,654	305,062	91,793	30.2	30.1	278,259	54,175	10,545	19.5	19.5	33,047	18,313	2,607	55.4	14.2
1975	987,922	294,920	93,342	29.9	31.6	293,651	53,825	11,005	18.3	20.4	32,951	18,358	2,836	55.7	15.4
1976	997,504	292,174	95,597	29.3	32.7	313,001	54,747	12,072	17.5	22.1	32,946	17,864	2,981	54.2	16.7
1977	993,008	288,543	97,453	29.1	33.8	318,241	56,731	13,154	17.8	23.2	31,716	17,416	3,106	54.9	17.8
1978	997,165	288,167	100,060	28.9	34.7	312,816	56,237	13,690	18.0	24.3	30,875	17,048	3,313	55.2	19.4
1979	1,000,562	288,625	102,292	28.8	35.4	302,075	54,456	14,040	18.0	25.8	31,239	17,245	3,583	55.2	20.8
1980	1,010,777	291,983	105,974	28.9	36.3	299,095	54,391	14,383	18.2	26.4	31,020	17,199	3,801	55.4	22.1
1981	1,019,246	294,867	108,442	28.9	36.8	296,798	54,811	15,014	18.5	27.4	31,357	17,633	4,023	56.2	22.8
1982	1,036,597	302,118	113,161	29.1	37.5	296,580	57,025	15,976	19.2	28.0	31,106	17,630	4,145	56.7	23.5
1983	1,054,242	307,225	115,611	29.1	37.6	290,931	58,868	17,081	20.2	29.0	31,280	17,976	4,495	57.5	25.0
1984	1,061,245	314,666	118,016	29.7	37.5	285,462	59,569	17,675	20.9	29.7	31,332	18,107	4,587	57.8	25.3
1985	1,066,439	321,439	121,439	30.1	37.8	287,213	61,278	18,298	21.3	29.9	31,291	18,323	4,682	58.6	25.6
1986	1,074,785	323,950	NA	30.1	NA	289,829	62,526	NA	21.6	NA	31,896	18,859	4,942	59.1	26.2
1987	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	32,367	19,312	5,103	59.7	26.4
1988	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	33,456	20,257	5,382	60.5	26.6

NA = Not available.

[1] Percentage of S/E degrees earned by females.

SOURCE: NSF, Division of Science Resources Studies.

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Appendix table 2-12. S/E degrees, by level and field: 1977-88

Field	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
						Bachelor's						
Total, all fields	288,543	288,157	288,625	291,983	294,867	302,118	307,225	314,666	321,739	323,950	NA	NA
Total science	246,962	240,746	234,905	232,743	230,799	234,327	234,271	238,135	243,868	246,889	NA	NA
Physical sciences	16,965	17,172	17,281	17,506	17,481	17,311	16,199	15,834	16,271	15,786	NA	NA
Mathematics	14,303	12,701	11,901	11,473	11,173	11,708	12,557	13,342	15,267	16,388	NA	NA
Computer science	6,426	7,224	8,769	11,213	15,233	20,431	24,678	32,435	39,121	42,195	NA	NA
Environmental sciences	5,653	6,003	6,082	6,155	6,694	7,061	7,298	7,925	7,576	6,076	NA	NA
Life sciences	78,472	77,138	75,085	71,617	68,086	65,041	63,237	59,613	57,812	56,465	NA	NA
Psychology	47,794	45,057	43,012	42,513	41,364	41,539	40,825	40,375	40,237	40,937	NA	NA
Social sciences	77,349	75,461	72,775	72,266	70,768	71,236	69,477	68,611	67,584	69,042	NA	NA
Total engineering	41,581	47,411	53,720	59,240	64,068	67,791	72,954	76,531	77,871	77,061	NA	NA
						Master's						
Total, all fields	56,731	56,237	54,456	54,391	54,811	57,025	58,868	59,569	61,278	62,526	NA	NA
Total science	39,842	39,222	38,263	37,545	37,438	38,431	39,147	39,217	40,072	41,212	NA	NA
Physical sciences	3,686	3,744	3,687	3,440	3,424	3,514	3,329	3,586	3,642	3,676	NA	NA
Mathematics	3,698	3,383	3,046	2,868	2,569	2,731	2,839	2,749	2,888	3,171	NA	NA
Computer science	2,798	3,038	3,055	3,647	4,218	4,935	5,321	6,190	7,101	8,070	NA	NA
Environmental sciences	1,659	1,832	1,777	1,793	1,876	2,012	1,959	1,982	2,160	2,234	NA	NA
Life sciences	10,707	10,711	10,719	10,278	9,731	9,824	9,720	9,330	8,757	8,572	NA	NA
Psychology	8,320	8,194	8,031	7,861	8,039	7,849	8,439	8,073	8,481	8,363	NA	NA
Social sciences	8,974	8,320	7,948	7,658	7,581	7,566	7,540	7,307	7,043	7,126	NA	NA
Total engineering	16,889	17,015	16,193	16,846	17,373	18,594	19,721	20,352	21,206	21,314	NA	NA
						Doctorates						
Total, all fields	17,416	17,048	17,245	17,199	17,633	17,630	17,976	18,107	18,323	18,859	19,312	20,257
Total science	14,773	14,625	14,755	14,720	15,105	14,984	15,195	15,194	15,157	15,483	15,600	16,067
Physical sciences	2,721	2,611	2,674	2,521	2,627	2,694	2,802	2,845	2,916	3,090	3,212	3,320
Mathematics	933	838	769	744	728	720	701	698	688	729	740	749
Computer science	31	121	210	218	232	220	286	295	310	399	450	514
Environmental sciences	694	623	646	628	583	657	637	614	617	589	628	726
Life sciences	4,266	4,369	4,501	4,715	4,786	4,844	4,756	4,877	4,902	4,806	4,813	5,121
Psychology	2,989	3,055	3,091	3,098	3,358	3,159	3,347	3,257	3,117	3,124	3,177	3,058
Social sciences	3,139	3,008	2,864	2,796	2,791	2,690	2,666	2,608	2,607	2,746	2,580	2,579
Total engineering	2,648	2,423	2,490	2,479	2,528	2,646	2,781	2,913	3,166	3,376	3,712	4,190

NA = Not available.

SOURCE: NSF, Division of Science Resources Studies.

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Appendix table 2-13. S/E doctorates of non-U.S. citizens, by visa type: 1978-88

Field	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total, all fields	17,048	17,245	17,199	17,633	17,630	17,976	18,107	18,323	18,859	19,312	20,257
Non-U.S. citizens, permanent visas	970	927	935	876	834	877	817	899	969	1,064	1,095
Non-U.S. citizens, temporary visas	2,506	2,606	2,643	2,892	3,051	3,328	3,609	3,960	4,056	4,364	4,838
Total science	14,625	14,755	14,720	15,105	14,984	15,195	15,194	15,157	15,483	15,600	16,067
Non-U.S. citizens, permanent visas	645	605	636	575	538	558	543	584	626	709	729
Non-U.S. citizens, temporary visas	1,738	1,791	1,792	1,950	2,021	2,158	2,340	2,541	2,684	2,832	3,115
Physical sciences	2,611	2,674	2,521	2,627	2,694	2,802	2,845	2,916	3,090	3,212	3,320
Non-U.S. citizens, permanent visas	183	165	151	147	119	120	119	135	133	147	137
Non-U.S. citizens, temporary visas	397	415	426	442	506	539	564	620	758	798	862
Mathematics	838	769	744	728	720	701	698	688	729	740	749
Non-U.S. citizens, permanent visas	47	51	62	43	41	46	36	42	36	51	43
Non-U.S. citizens, temporary visas	155	149	139	186	192	209	232	238	272	302	304
Computer science	121	210	218	232	220	286	295	310	399	450	514
Non-U.S. citizens, permanent visas	5	12	13	20	12	27	17	24	47	32	42
Non-U.S. citizens, temporary visas	26	32	43	40	59	72	89	89	123	143	174
Environmental sciences	623	646	628	583	657	637	614	617	589	628	726
Non-U.S. citizens, permanent visas	22	34	26	16	29	30	25	32	24	25	30
Non-U.S. citizens, temporary visas	68	71	80	85	81	106	106	119	106	125	137
Life sciences	4,369	4,501	4,715	4,786	4,844	4,756	4,877	4,902	4,806	4,813	5,121
Non-U.S. citizens, permanent visas	185	161	186	159	140	150	149	151	165	208	262
Non-U.S. citizens, temporary visas	559	562	592	613	603	629	675	779	711	780	898
Psychology	3,055	3,091	3,098	3,358	3,159	3,347	3,257	3,117	3,124	3,177	3,058
Non-U.S. citizens, permanent visas	54	45	50	47	47	64	51	59	65	59	59
Non-U.S. citizens, temporary visas	61	73	71	80	65	79	88	81	81	85	84
Social sciences	3,008	2,864	2,796	2,791	2,690	2,666	2,608	2,607	2,746	2,580	2,579
Non-U.S. citizens, permanent visas	149	137	148	143	150	121	146	141	156	187	156
Non-U.S. citizens, temporary visas	472	489	441	504	515	524	586	615	633	599	656
Total engineering	2,423	2,490	2,479	2,528	2,646	2,781	2,913	3,166	3,376	3,712	4,190
Non-U.S. citizens, permanent visas	325	322	299	301	296	319	274	315	343	355	366
Non-U.S. citizens, temporary visas	768	815	851	942	1,030	1,170	1,269	1,419	1,372	1,532	1,723

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-8.

Appendix table 2-14. S/E Ph.D.s of U.S. citizens, by field and gender: 1975-88

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total, all fields	27,081	27,269	26,119	25,291	25,464	25,221	25,061	24,388	24,358	24,026	23,363	23,081	22,991	23,172
Male	20,662	20,427	19,155	17,936	17,580	16,875	16,360	15,559	15,119	14,729	14,217	13,633	13,581	13,667
Female	6,419	6,842	6,964	7,355	7,884	8,346	8,701	8,829	9,239	9,297	9,146	9,448	9,410	9,505
Total non-S/E	13,066	13,496	12,712	12,205	12,207	12,042	11,763	11,366	11,255	11,049	10,687	10,466	10,428	10,325
Male	9,058	9,189	8,376	7,642	7,367	6,967	6,476	6,071	5,852	5,612	5,360	4,982	5,015	4,934
Female	4,008	4,307	4,336	4,563	4,840	5,075	5,287	5,295	5,403	5,437	5,327	5,484	5,413	5,391
Total S/E	14,015	13,773	13,407	13,086	13,257	13,179	13,298	13,022	13,103	12,977	12,676	12,615	12,563	12,847
Male	11,604	11,238	10,779	10,294	10,213	9,908	9,884	9,488	9,267	9,117	8,857	8,651	8,566	8,733
Female	2,411	2,535	2,628	2,792	3,044	3,271	3,414	3,534	3,836	3,860	3,819	3,964	3,997	4,114
Total science	12,299	12,216	11,935	11,825	11,964	11,924	12,128	11,853	11,940	11,738	11,397	11,232	11,005	11,069
Male	9,920	9,715	9,349	9,063	8,959	8,717	8,767	8,393	8,187	7,966	7,697	7,410	7,157	7,133
Female	2,379	2,501	2,586	2,762	3,005	3,207	3,361	3,460	3,753	3,772	3,700	3,822	3,848	3,936
Physics	925	911	833	804	800	715	721	706	709	739	698	694	699	721
Male	880	879	792	775	756	670	676	651	658	685	636	638	634	664
Female	45	32	41	29	44	45	45	55	51	54	62	56	65	57
Chemistry	1,392	1,264	1,238	1,174	1,240	1,169	1,235	1,285	1,355	1,332	1,345	1,320	1,381	1,373
Male	1,264	1,129	1,109	1,025	1,070	984	1,056	1,076	1,121	1,083	1,084	1,044	1,085	1,067
Female	128	135	129	149	170	185	179	209	234	249	261	276	296	306
Environmental sciences	492	508	559	518	532	512	472	528	483	474	442	422	425	507
Male	462	458	512	464	482	456	425	436	402	378	354	344	342	392
Female	30	50	47	54	50	56	47	92	81	96	88	78	83	115
Mathematical sciences	848	748	690	619	552	520	482	458	411	407	376	366	345	341
Male	761	663	603	528	460	447	402	386	335	333	306	297	280	282
Female	87	85	87	91	92	73	80	72	76	74	70	69	65	59
Computer sciences	0	0	24	85	163	156	168	143	180	178	189	202	243	284
Male	0	0	20	78	137	137	148	126	153	153	165	165	193	245
Female	0	0	4	7	26	19	20	17	27	25	24	37	50	39
Life sciences	3,473	3,497	3,396	3,522	3,674	3,849	3,891	3,964	3,859	3,910	3,829	3,704	3,568	3,658
Male	2,760	2,804	2,702	2,744	2,814	2,871	2,859	2,851	2,688	2,773	2,678	2,513	2,375	2,373
Female	713	693	694	778	860	978	1,032	1,113	1,171	1,137	1,151	1,191	1,193	1,285
Psychology	2,552	2,727	2,774	2,804	2,850	2,859	3,111	2,876	3,044	2,935	2,805	2,766	2,752	2,641
Male	1,746	1,832	1,767	1,770	1,700	1,637	1,746	1,556	1,576	1,440	1,396	1,330	1,262	1,179
Female	806	895	1,007	1,034	1,150	1,222	1,365	1,320	1,468	1,495	1,409	1,436	1,490	1,462
Other social sciences	2,617	2,561	2,421	2,299	2,153	2,144	2,048	1,893	1,899	1,763	1,713	1,758	1,592	1,544
Male	2,047	1,950	1,844	1,679	1,540	1,515	1,455	1,311	1,254	1,121	1,078	1,079	986	931
Female	570	611	577	620	613	629	593	582	645	642	635	679	606	613
Engineering	1,716	1,557	1,472	1,261	1,293	1,255	1,170	1,169	1,163	1,239	1,279	1,383	1,558	1,778
Male	1,684	1,523	1,430	1,231	1,254	1,191	1,117	1,095	1,080	1,151	1,160	1,241	1,409	1,600
Female	32	34	42	30	39	64	53	74	83	88	119	142	149	178

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-9.

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Appendix table 2-15. Ph.D.s by citizenship, selected racial/ethnic group, and gender: 1975-88

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total U.S. citizens														
S/E Ph.D.s	14,015	13,773	13,407	13,086	13,257	13,179	13,298	13,022	13,103	12,977	12,676	12,615	12,563	12,847
Male	11,604	11,238	10,779	10,294	10,213	9,908	9,884	9,488	9,267	9,117	8,857	8,651	8,566	8,733
Female	2,411	2,535	2,628	2,792	3,044	3,271	3,414	3,534	3,836	3,860	3,819	3,964	3,997	4,114
Non-S/E Ph.D.s	13,066	13,496	12,712	12,205	12,207	12,042	11,763	11,366	11,255	11,049	10,687	10,466	10,428	10,325
Male	9,058	9,189	8,376	7,642	7,367	6,967	6,476	6,071	5,852	5,612	5,360	4,982	5,015	4,934
Female	4,008	4,307	4,336	4,563	4,840	5,075	5,287	5,295	5,403	5,437	5,327	5,484	5,413	5,391
White U.S. citizens														
S/E Ph.D.s	12,837	12,586	12,100	11,484	11,601	11,647	11,873	11,804	11,866	11,684	11,424	11,406	11,260	11,559
Male	10,621	10,266	9,729	9,048	8,944	8,763	8,835	8,638	8,434	8,223	8,023	7,844	7,704	7,845
Female	2,216	2,320	2,371	2,436	2,657	2,884	3,038	3,166	3,432	3,461	3,401	3,562	3,556	3,714
Non-S/E Ph.D.s	11,515	11,787	10,965	10,327	10,319	10,346	10,107	9,872	9,833	9,665	9,333	9,220	9,210	9,126
Male	8,015	8,105	7,282	6,525	6,317	6,085	5,624	5,349	5,175	4,947	4,782	4,459	4,468	4,451
Female	3,500	3,682	3,683	3,802	4,002	4,261	4,483	4,523	4,658	4,718	4,551	4,761	4,742	4,675
Black U.S. citizens														
S/E Ph.D.s	240	246	265	278	288	261	273	270	269	282	260	238	222	231
Male	176	161	181	175	172	139	152	150	142	145	141	119	109	127
Female	64	85	84	103	116	122	121	120	127	137	119	119	113	104
Non-S/E Ph.D.s	759	849	851	755	768	771	740	777	653	671	652	585	545	574
Male	474	491	503	409	379	360	347	333	271	282	238	203	208	184
Female	285	358	348	346	389	411	393	444	382	389	414	382	337	390
Hispanic U.S. citizens														
S/E Ph.D.s	128	116	159	160	173	166	191	219	221	250	237	264	293	319
Male	113	104	130	120	126	121	135	157	128	171	144	168	169	196
Female	15	12	29	40	47	45	56	62	93	79	93	96	124	123
Non-S/E Ph.D.s	175	224	264	313	289	246	273	316	318	286	324	308	326	275
Male	129	149	180	197	182	135	140	187	160	143	156	135	164	125
Female	46	75	84	116	107	111	133	129	158	143	168	173	162	150
Asian U.S. citizens														
S/E Ph.D.s	192	240	246	275	301	323	327	318	341	380	371	394	440	441
Male	158	193	196	217	236	237	244	218	233	267	259	281	317	331
Female	34	47	50	58	65	86	83	100	108	113	112	113	123	110
Non-S/E Ph.D.s	94	94	93	115	127	135	138	134	151	132	145	137	102	171
Male	64	51	55	70	75	76	71	63	79	71	70	67	52	82
Female	30	43	38	45	52	59	67	71	72	61	75	70	50	89
Foreign citizens, permanent residents (both genders)														
S/E Ph.D.s	1,246	1,078	979	970	927	935	876	834	877	817	899	969	1,064	1,095
Non-S/E Ph.D.s	468	416	389	374	393	356	405	394	398	407	425	463	514	516
Foreign citizens, temporary residents (both genders)														
S/E Ph.D.s	2,742	2,675	2,601	2,506	2,606	2,643	2,892	3,051	3,328	3,609	3,960	4,056	4,364	4,838
Non-S/E Ph.D.s	794	854	847	915	981	1,001	1,048	1,153	1,171	1,221	1,269	1,219	1,245	1,338

SOURCE: NSF, Division of Science Resources Studies.

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Appendix table 2-16. Enrollment and source of support of full-time S/E graduate students in doctorate-granting institutions, by field: 1980-88

Field and source of support	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	208,232	212,083	216,012	223,135	224,701	227,486	236,748	240,966	245,463
Federal	44,755	43,244	41,086	41,801	41,911	42,794	45,258	46,925	48,749
Institutional support	82,278	85,947	88,632	91,340	94,716	96,590	101,784	104,539	107,326
Other outside support	19,869	21,125	22,360	22,839	22,895	24,731	24,870	23,485	24,186
Self-support	61,330	61,767	63,934	67,155	65,179	63,371	64,836	66,017	65,202
Total science	166,293	167,266	167,325	170,445	170,727	172,669	177,717	180,614	183,807
Federal	33,648	32,321	30,081	29,898	30,409	31,611	32,950	33,905	34,927
Institutional support	69,644	71,847	73,463	75,226	77,609	78,444	81,762	83,503	86,016
Other outside support	13,717	14,243	14,723	14,898	14,369	15,232	14,820	13,956	14,340
Self-support	49,284	48,855	49,058	50,423	48,340	47,382	48,185	49,250	48,524
Physical sciences	22,254	22,600	23,330	24,502	25,147	25,938	27,069	27,652	27,832
Federal	7,655	7,899	7,644	8,050	8,551	8,723	9,434	9,616	9,750
Institutional support	11,928	11,924	12,581	13,166	13,281	13,536	14,013	14,408	14,473
Other outside support	1,307	1,416	1,740	1,688	1,791	2,046	1,907	1,833	1,959
Self-support	1,364	1,361	1,365	1,598	1,524	1,633	1,715	1,795	1,650
Environmental sciences	10,265	10,491	10,873	11,497	11,266	10,871	10,862	10,097	9,893
Federal	3,369	2,965	2,808	2,831	2,811	2,933	3,014	2,855	2,771
Institutional support	3,648	3,916	4,097	4,073	4,177	3,975	4,192	4,043	4,146
Other outside support	1,042	1,129	1,199	1,256	1,222	1,375	1,162	988	1,003
Self-support	2,206	2,481	2,769	3,337	3,056	2,588	2,494	2,211	1,973
Mathematical sciences	9,368	9,680	10,174	10,316	10,613	11,160	11,727	12,364	12,791
Federal	842	782	802	747	755	930	992	1,084	1,160
Institutional support	6,340	6,457	6,827	7,120	7,389	7,758	8,170	8,506	8,783
Other outside support	519	526	536	507	626	543	587	536	594
Self-support	1,667	1,915	2,009	1,942	1,843	1,929	1,978	2,238	2,254
Computer science	5,900	6,465	7,908	9,276	10,108	12,374	13,389	13,639	13,811
Federal	879	944	973	1,045	1,215	1,568	1,818	2,022	2,153
Institutional support	1,961	2,314	2,579	3,073	3,486	4,084	4,315	4,750	4,898
Other outside support	602	598	670	689	705	1,261	1,424	1,115	1,151
Self-support	2,458	2,609	3,686	4,469	4,702	5,461	5,832	5,752	5,609
Agricultural sciences	9,591	9,630	9,500	9,420	9,323	8,721	8,852	8,611	8,677
Federal	1,778	1,710	1,654	1,510	1,346	1,502	1,600	1,660	1,663
Institutional support	3,359	3,448	3,444	3,576	3,821	3,369	3,529	3,479	3,423
Other outside support	2,023	2,116	2,008	2,090	1,942	1,852	1,742	1,582	1,702
Self-support	2,431	2,356	2,394	2,244	2,214	1,998	1,981	1,890	1,889
Biological sciences	35,817	35,454	35,226	35,234	35,688	35,696	36,609	37,223	38,235
Federal	10,725	10,505	10,055	10,171	10,333	10,630	11,069	11,827	12,444
Institutional support	15,546	15,674	15,796	15,869	16,403	16,367	17,006	17,077	17,380
Other outside support	2,731	2,746	3,053	3,172	3,088	3,244	3,050	3,173	3,492
Self-support	6,815	6,529	6,322	6,022	5,864	5,455	5,484	5,146	4,919
Psychology	21,580	21,544	21,103	22,150	21,601	21,341	21,997	22,567	23,360
Federal	3,189	2,895	2,283	1,980	1,942	1,958	1,894	1,932	2,045
Institutional support	7,869	8,614	8,557	8,784	9,219	9,518	9,917	9,853	10,263
Other outside support	1,438	1,505	1,377	1,316	1,325	1,326	1,334	1,214	1,007
Self-support	9,084	8,530	8,886	10,070	9,115	8,539	8,852	9,568	10,045
Social sciences	51,518	51,402	49,211	48,050	46,981	46,568	47,212	48,461	49,208
Federal	5,211	4,621	3,862	3,564	3,456	3,367	3,129	2,909	2,941
Institutional support	18,993	19,500	19,582	19,565	19,833	19,837	20,620	21,387	22,650
Other outside support	4,055	4,207	4,140	4,180	3,670	3,585	3,614	3,515	3,432
Self-support	23,259	23,074	21,627	20,741	20,022	19,779	19,849	20,650	20,185
Total engineering	41,939	44,817	48,687	52,690	53,974	54,817	59,031	60,352	61,656
Federal	11,107	10,923	11,005	11,903	11,502	11,183	12,308	13,020	13,822
Institutional support	12,634	14,100	15,169	16,114	17,107	18,146	20,022	21,036	21,310
Other outside support	6,152	6,882	7,637	7,941	8,526	9,499	10,050	9,529	9,846
Self-support	12,046	12,912	14,876	16,732	16,839	15,989	16,651	16,767	16,678

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-10.

Appendix table 2-17. Full-time S/E graduate students in doctorate-granting institutions, by field and type of major support: 1980-88

Field and type of major support	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total science and engineering	208,232	212,083	216,012	223,135	224,701	227,486	236,748	240,966	245,463
Fellowships and traineeships	30,867	29,962	29,275	29,275	29,483	30,137	30,792	30,189	31,191
Research assistantships	49,333	50,469	50,335	52,590	55,097	58,171	63,141	66,887	70,825
Teaching assistantships	49,878	51,851	53,997	55,762	56,884	57,703	58,576	58,938	59,410
Other types of support	16,824	18,034	18,471	18,361	18,058	18,104	19,403	18,935	18,835
Self-support	61,330	61,767	63,934	67,147	65,179	63,371	64,836	66,017	65,202
Total science	166,293	167,266	167,325	170,445	170,727	172,669	177,717	180,614	183,807
Fellowships and traineeships	26,264	24,930	23,859	23,780	23,967	24,652	25,099	24,692	25,813
Research assistantships	35,405	36,075	35,740	37,051	38,911	40,343	42,781	44,882	47,497
Teaching assistantships	42,633	43,696	45,045	45,898	46,557	47,157	47,661	48,028	48,505
Other types of support	12,707	13,710	13,623	13,301	12,952	13,135	13,991	13,762	13,468
Self-support	49,284	48,855	49,058	50,415	48,340	47,382	48,185	49,250	48,524
Physical sciences	22,254	22,600	23,330	24,502	25,147	25,938	27,069	27,652	27,832
Fellowships and traineeships	2,183	2,237	2,285	2,288	2,413	2,301	2,376	2,326	2,356
Research assistantships	8,258	8,524	8,683	9,060	9,517	10,174	10,896	11,455	11,862
Teaching assistantships	9,894	9,976	10,361	10,904	10,977	11,119	11,324	11,413	11,238
Other types of support	555	502	636	652	716	711	758	663	726
Self-support	1,364	1,361	1,365	1,598	1,524	1,633	1,715	1,795	1,650
Environmental sciences	10,265	10,491	10,873	11,497	11,266	10,871	10,862	10,097	9,893
Fellowships and traineeships	1,107	1,095	1,140	1,130	1,107	1,131	974	896	899
Research assistantships	3,664	3,402	3,265	3,481	3,506	3,668	3,786	3,619	3,820
Teaching assistantships	2,563	2,541	2,737	2,752	2,743	2,533	2,539	2,397	2,436
Other types of support	725	972	962	797	854	951	1,069	974	765
Self-support	2,206	2,481	2,769	3,337	3,056	2,588	2,494	2,211	1,973
Mathematical sciences	9,368	9,680	10,174	10,316	10,613	11,160	11,727	12,364	12,791
Fellowships and traineeships	891	799	788	800	901	992	1,032	1,030	1,117
Research assistantships	773	732	822	776	846	969	1,012	1,072	1,166
Teaching assistantships	5,373	5,536	5,817	6,140	6,325	6,545	6,897	7,207	7,341
Other types of support	664	698	738	658	698	725	808	817	913
Self-support	1,667	1,915	2,009	1,942	1,843	1,929	1,978	2,238	2,254
Computer science	5,900	6,465	7,908	9,276	10,108	12,374	13,389	13,639	13,811
Fellowships and traineeships	367	473	463	524	612	807	893	837	870
Research assistantships	1,023	1,068	1,151	1,367	1,582	2,017	2,284	2,782	2,984
Teaching assistantships	1,409	1,742	1,955	2,311	2,646	3,084	3,109	3,258	3,320
Other types of support	643	573	653	613	566	1,005	1,271	1,010	1,028
Self-support	2,458	2,609	3,686	4,461	4,702	5,461	5,832	5,752	5,609
Agricultural sciences	9,591	9,630	9,500	9,420	9,323	8,721	8,852	8,611	8,677
Fellowships and traineeships	772	793	779	759	666	657	636	543	507
Research assistantships	4,484	4,647	4,558	4,509	4,608	4,306	4,590	4,492	4,438
Teaching assistantships	888	805	883	879	837	824	752	730	832
Other types of support	1,016	1,029	886	1,029	998	936	893	956	1,011
Self-support	2,431	2,356	2,394	2,244	2,214	1,998	1,981	1,890	1,889
Biological sciences	35,817	35,454	35,226	35,234	35,688	35,696	36,609	37,223	38,235
Fellowships and traineeships	8,160	7,967	7,845	7,946	7,995	8,194	8,437	8,695	8,928
Research assistantships	9,545	9,801	9,774	10,023	10,797	11,123	11,977	12,829	13,935
Teaching assistantships	9,120	9,037	9,155	8,972	8,918	8,913	8,605	8,320	8,255
Other types of support	2,177	2,120	2,130	2,271	2,114	2,011	2,106	2,233	2,198
Self-support	6,815	6,529	6,322	6,022	5,864	5,455	5,484	5,146	4,919
Psychology	21,580	21,544	21,103	22,150	21,601	21,341	21,997	22,567	23,360
Fellowships and traineeships	3,447	3,167	2,915	2,546	2,635	2,769	2,603	2,553	2,570
Research assistantships	2,342	2,664	2,510	2,669	2,759	2,864	2,884	2,979	3,480
Teaching assistantships	4,424	4,604	4,550	4,633	4,660	4,797	4,986	5,009	5,145
Other types of support	2,283	2,579	2,242	2,232	2,432	2,372	2,672	2,458	2,120
Self-support	9,084	8,530	8,886	10,070	9,115	8,539	8,852	9,568	10,045

(continued)

Appendix table 2-17. (Continued)

Field and type of major support	1980	1981	1982	1983	1984	1985	1986	1987	1988
Social sciences	51,518	51,402	49,211	48,050	46,981	46,568	47,212	48,461	49,208
Fellowships and traineeships	9,337	8,399	7,644	7,787	7,638	7,801	8,148	7,812	8,566
Research assistantships	5,316	5,237	4,977	5,166	5,296	5,222	5,352	5,654	5,812
Teaching assistantships	8,962	9,455	9,587	9,307	9,451	9,342	9,449	9,694	9,938
Other types of support	4,644	5,237	5,376	5,049	4,574	4,424	4,414	4,651	4,707
Self-support	23,259	23,074	21,627	20,741	20,022	19,779	19,849	20,650	20,185
Total engineering	41,939	44,817	48,687	52,690	53,974	54,817	59,031	60,352	61,656
Fellowships and traineeships	4,603	5,032	5,416	5,495	5,516	5,485	5,693	5,497	5,378
Research assistantships	13,928	14,394	14,595	15,539	16,186	17,828	20,360	22,005	23,328
Teaching assistantships	7,245	8,155	8,952	9,864	10,327	10,546	10,915	10,910	10,905
Other types of support	4,117	4,324	4,848	5,060	5,106	4,969	5,412	5,173	5,367
Self-support	12,046	12,912	14,876	16,732	16,839	15,989	16,651	16,767	16,678

SOURCE: NSF, Division of Science Resources Studies.

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Appendix table 2-18: Federal support of graduate S/E students, by selected Federal agency and type of support: 1980-88

Type and source of major support	1980	1981	1982	1983	1984	1985	1986	1987	1988
Total, all types									
Total Federal	52,939	50,897	47,206	47,333	47,476	48,716	51,060	53,093	54,852
DOD	5,239	5,647	5,861	6,884	7,049	7,230	7,852	8,685	9,309
Total HHS	19,377	18,018	16,040	15,007	15,140	15,898	16,417	17,176	17,867
NIH	11,560	11,283	10,860	10,823	10,996	11,130	11,892	12,971	13,784
Other HHS	7,817	6,735	5,180	4,184	4,144	4,768	4,525	4,205	4,083
NSF	9,243	9,084	9,207	9,474	9,806	10,151	10,810	11,193	11,556
All other Federal	19,080	18,148	16,098	15,968	15,481	15,437	15,961	16,039	16,120
Fellowships									
Total Federal	4,634	4,112	4,183	4,101	4,060	4,360	4,511	4,378	4,538
DOD	255	182	201	257	238	262	295	353	359
Total HHS	1,247	1,024	904	813	809	877	822	869	889
NIH	777	720	656	575	612	636	654	706	728
Other HHS	470	304	248	238	197	241	168	163	161
NSF	1,315	1,247	1,302	1,304	1,343	1,396	1,512	1,483	1,585
All other Federal	1,817	1,659	1,776	1,727	1,670	1,825	1,882	1,673	1,705
Traineeships									
Total Federal	13,808	12,632	10,301	9,193	9,011	9,002	8,767	8,921	8,681
DOD	70	80	33	79	75	53	84	139	140
Total HHS	11,427	10,411	8,913	7,744	7,585	7,703	7,439	7,299	7,216
NIH	5,040	4,809	4,715	4,530	4,359	4,143	3,983	4,261	4,195
Other HHS	6,387	5,602	4,198	3,214	3,226	3,560	3,456	3,038	3,021
NSF	193	134	72	47	42	56	27	82	68
All other Federal	2,118	2,007	1,283	1,323	1,309	1,190	1,217	1,401	1,257
Research assistantships									
Total Federal	29,066	28,940	28,025	28,869	29,154	30,157	32,533	34,738	36,334
DOD	2,924	3,280	3,460	3,920	4,052	4,168	4,629	5,565	5,934
Total HHS	5,968	6,011	5,721	5,921	6,269	6,814	7,655	8,405	9,230
NIH	5,371	5,454	5,206	5,374	5,687	6,058	6,932	7,575	8,446
Other HHS	597	557	515	547	582	756	723	830	784
NSF	7,604	7,578	7,723	8,030	8,251	8,531	9,070	9,444	9,752
All other Federal	12,570	12,071	11,121	10,998	10,582	10,644	11,179	11,324	11,418
Teaching assistantships									
Total Federal	603	549	382	469	383	539	499	439	444
DOD	0	0	0	0	0	0	0	0	
Total HHS	132	118	102	111	71	96	111	155	138
NIH	82	75	49	74	44	57	82	127	113
Other HHS	50	43	53	37	27	39	29	28	25
NSF	30	58	24	25	24	43	73	26	55
All other Federal	441	373	256	333	288	400	315	258	251
Other types of support									
Total Federal	4,828	4,664	4,315	4,701	4,868	4,658	4,750	4,617	4,855
DOD	1,990	2,105	2,167	2,628	2,684	2,747	2,844	2,628	2,876
Total HHS	603	454	400	418	406	408	390	448	394
NIH	290	225	234	270	294	236	241	302	302
Other HHS	313	229	166	148	112	172	149	146	92
NSF	101	67	86	68	146	125	128	158	96
All other Federal	2,134	2,038	1,662	1,587	1,632	1,378	1,388	1,383	1,489

DOD = Department of Defense; HHS = Department of Health and Human Services; NIH = National Institutes of Health; NSF = National Science Foundation.

SOURCE: NSF, Division of Science Resources Studies.

See figure 2-11.

Appendix table 2-19. Academic[1] doctoral scientists and engineers, by age and field: selected years

Field	Years	Number	Age (years)				
			Under 30	30-39	40-49	50-59	60+
			Percent				
Total scientists and engineers	1977	157,088	3.4	41.1	29.6	19.0	6.9
	1981	179,224	2.5	35.5	32.2	20.7	9.1
	1983	187,554	1.8	31.4	34.8	21.6	10.3
	1985	202,019	1.6	30.3	35.7	21.0	11.3
	1987	209,384	1.2	27.7	37.0	22.4	11.5
Total scientists	1977	141,373	3.5	41.6	28.9	18.8	7.1
	1981	161,247	2.6	36.4	31.6	20.1	9.3
	1983	167,305	1.8	32.0	34.4	21.3	10.4
	1985	180,505	1.5	30.7	36.0	20.4	11.3
	1987	185,746	1.2	28.0	37.6	21.7	11.3
Physical scientists	1977	25,556	4.2	41.4	30.7	16.8	6.9
	1981	26,786	3.4	30.5	34.5	20.6	11.0
	1983	26,453	2.5	24.4	38.8	22.6	11.8
	1985	28,206	2.2	25.3	37.2	22.7	12.6
	1987	28,729	1.8	23.0	35.8	26.8	12.4
Mathematical scientists	1977	11,781	4.5	48.6	27.9	13.2	5.7
	1981	12,274	3.1	35.0	38.3	16.6	7.0
	1983	12,770	2.2	28.2	42.3	19.1	8.2
	1985	13,027	2.8	25.4	40.1	22.2	9.5
	1987	13,031	2.7	26.7	38.5	22.9	9.2
Computer specialists	1977	2,118	4.6	52.2	27.9	13.4	1.9
	1981	2,954	3.0	45.4	31.6	15.5	4.5
	1983	3,905	2.1	45.8	32.0	13.1	6.9
	1985	5,124	1.9	38.8	40.3	12.9	6.0
	1987	5,439	1.6	29.6	47.4	15.6	5.8
Environmental scientists	1977	6,120	1.5	43.1	31.4	18.3	5.6
	1981	6,613	3.1	33.3	37.7	17.8	8.1
	1983	6,519	1.8	35.3	31.6	21.2	10.1
	1985	7,097	1.3	30.6	34.6	23.1	10.2
	1987	7,375	1.8	27.8	37.3	23.3	9.7
Life scientists	1977	45,643	3.5	41.7	27.8	19.6	7.3
	1981	54,437	2.9	39.5	29.5	19.7	8.4
	1983	57,315	1.9	34.9	32.8	20.7	9.6
	1985	61,788	1.4	34.0	34.5	19.9	10.2
	1987	64,738	0.9	32.4	35.7	20.4	10.5
Psychologists	1977	16,572	5.1	41.9	28.0	19.3	5.7
	1981	19,034	2.9	41.6	27.9	20.1	7.4
	1983	19,377	1.5	37.8	30.5	21.6	8.4
	1985	21,493	1.5	36.6	31.6	19.7	10.5
	1987	22,012	1.0	29.9	35.8	21.6	11.5
Social scientists	1977	33,583	2.2	38.1	29.5	21.2	8.9
	1981	39,149	1.3	33.8	31.2	22.2	11.5
	1983	40,966	1.1	29.5	34.1	22.5	12.7
	1985	43,770	0.9	27.2	38.1	20.1	13.7
	1987	44,422	0.7	24.2	40.9	20.5	13.4
Total engineers	1977	15,715	1.8	36.2	36.0	21.1	4.9
	1981	17,977	1.2	27.4	37.8	25.9	7.8
	1983	20,249	2.1	26.1	38.2	24.0	9.7
	1985	21,514	2.2	27.6	33.1	25.2	11.9
	1987	23,638	1.6	25.3	32.3	28.0	12.8

[1] Includes individuals employed in 4-year colleges and universities only.

Note: Percentages will not add to 100 because "no report" is omitted.

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

See table 2-3 in text.

Appendix table 2-20. Academic doctoral scientists and engineers, by primary work activity and field: selected years

Field		Total	Research and development				Management of R&D	Teaching	Consulting	Other
			Total	Basic research	Applied research	Development				
Total scientists and engineers	1981	179,224	52,450	37,746	13,689	1,015	4,363	99,247	772	22,392
	1983	187,554	54,536	39,443	13,584	1,509	3,021	100,452	684	28,861
	1985	202,019	60,550	43,579	15,653	1,318	3,937	103,652	1,204	32,676
	1987	209,384	73,227	48,403	24,013	811	3,892	101,835	479	29,951
Total scientists	1981	161,247	48,334	36,167	11,344	823	3,440	88,787	562	20,124
	1983	167,305	49,318	37,210	11,138	970	2,349	89,233	618	25,787
	1985	180,505	55,377	41,194	13,269	914	2,869	91,761	1,064	29,434
	1987	185,746	65,439	45,893	19,087	459	2,583	90,370	452	26,902
Physical scientists	1981	26,786	9,704	7,795	1,650	259	828	14,118	53	2,083
	1983	26,453	9,334	7,510	1,551	273	890	13,044	30	3,182
	1985	28,206	10,695	8,703	1,745	247	875	13,545	14	3,077
	1987	28,729	11,931	9,160	2,566	205	782	13,535	45	2,436
Mathematical scientists	1981	12,274	2,015	1,631	319	21	44	9,152	3	1,077
	1983	12,770	2,051	1,659	348	44	57	9,214	79	1,369
	1985	13,027	2,396	2,089	304	3	73	8,904	119	1,535
	1987	13,031	2,983	2,660	321	2	33	8,735	8	1,272
Computer specialists	1981	2,954	823	389	181	253	78	1,469	63	521
	1983	3,905	1,010	488	211	311	61	2,117	33	684
	1985	5,124	1,392	744	337	311	89	2,629	68	946
	1987	5,439	1,501	865	561	75	105	2,681	27	1,125
Environmental scientists	1981	6,613	2,378	1,660	642	76	376	3,436	0	423
	1983	6,519	2,319	1,755	564	0	253	3,250	13	684
	1985	7,097	2,701	1,940	721	40	350	3,231	23	792
	1987	7,375	3,259	2,166	1,075	18	224	3,256	6	630
Life scientists	1981	54,437	25,788	20,156	5,509	123	1,214	20,400	151	6,884
	1983	57,315	26,526	21,078	5,223	225	756	20,805	311	8,917
	1985	61,788	29,105	22,749	6,104	252	1,008	20,676	342	10,657
	1987	64,738	34,059	24,377	9,567	115	986	19,883	220	9,590
Psychologists	1981	19,034	3,237	2,095	1,116	26	282	11,620	119	3,776
	1983	19,377	3,104	2,040	1,040	24	113	11,478	121	4,561
	1985	21,493	3,556	2,074	1,447	35	125	11,953	325	5,534
	1987	22,012	4,213	2,547	1,633	33	150	12,606	81	4,962
Social scientists	1981	39,149	4,433	2,441	1,927	65	618	28,592	146	5,360
	1983	40,966	4,974	2,680	2,201	93	219	29,325	58	6,390
	1985	43,770	5,532	2,895	2,611	26	349	30,823	173	6,893
	1987	44,422	7,493	4,118	3,364	11	303	29,674	65	6,887
Total engineers	1981	17,977	4,116	1,579	2,345	192	923	10,460	210	2,268
	1983	20,249	5,218	2,233	2,446	539	672	11,219	66	3,074
	1985	21,514	5,173	2,385	2,384	404	1,068	11,891	140	3,242
	1987	23,638	7,788	2,510	4,926	352	1,309	11,465	27	3,049

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

Science & Engineering Indicators—1989

Appendix table 2-21. Academic doctoral scientists and engineers who teach, by field and rank: selected years

Field	Year	Total	Professor	Associate professor	Assistant professor	Instructor	Other	No report
Total scientists and engineers	1981	130,597	57,295	38,257	28,714	1,237	4,133	326
	1983	135,990	62,358	40,789	26,529	745	4,171	1,398
	1985	143,360	64,103	41,265	29,110	1,453	6,550	879
	1987	156,739	72,543	44,282	30,483	1,129	7,665	637
Total scientists	1981	117,417	50,089	34,577	26,774	1,237	3,831	326
	1983	121,088	54,311	36,557	24,267	743	3,918	1,292
	1985	127,583	56,228	37,181	25,965	1,451	6,005	753
	1987	139,139	62,843	40,041	27,432	1,095	7,145	583
Physical scientists	1981	18,423	9,938	4,745	2,701	134	686	61
	1983	17,656	10,546	4,074	2,281	102	521	132
	1985	18,749	10,677	4,100	2,669	229	947	127
	1987	20,252	11,824	4,385	2,752	81	1,136	74
Mathematical scientists	1981	10,804	4,924	3,377	2,125	160	177	25
	1983	11,289	5,295	3,523	2,148	115	132	76
	1985	11,567	5,702	3,136	2,292	142	230	65
	1987	12,052	6,067	3,094	2,394	157	333	7
Computer scientists	1981	1,950	579	717	549	30	54	0
	1983	2,559	842	898	688	5	117	9
	1985	3,619	1,009	1,276	1,039	46	247	2
	1987	3,983	1,055	1,523	1,168	17	213	7
Environmental scientists	1981	4,416	1,972	1,319	1,034	6	79	0
	1983	4,505	2,073	1,291	957	4	129	51
	1985	4,550	2,251	1,227	915	26	117	14
	1987	5,168	2,327	1,371	1,147	20	286	17
Life scientists	1981	33,893	13,278	10,248	8,140	535	1,528	89
	1983	35,415	14,911	10,693	7,497	258	1,669	387
	1985	35,956	14,683	11,038	7,437	423	2,197	178
	1987	42,391	18,296	12,085	8,711	511	2,488	300
Psychologists	1981	14,902	5,779	4,346	3,876	101	584	100
	1983	14,956	6,157	4,822	3,195	110	429	243
	1985	16,029	6,649	4,826	3,328	252	822	152
	1987	17,166	7,518	5,157	3,372	126	911	82
Social scientists	1981	33,029	13,619	9,825	8,349	271	723	51
	1983	34,708	14,487	11,256	7,501	149	921	394
	1985	37,113	15,257	11,578	8,285	333	1,445	215
	1987	38,127	15,756	12,426	7,888	183	1,778	96
Total engineers	1981	13,180	7,206	3,680	1,940	0	302	0
	1983	14,902	8,047	4,232	2,262	2	253	106
	1985	15,777	7,875	4,084	3,145	2	545	126
	1987	17,600	9,700	4,241	3,051	34	520	54

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

Appendix table 3-1. Total and scientist/engineer employment by industry: 1980, 1988, and projected to 2000

Industry	Number of jobs					Annual rate of change	
			Projected 2000				
	1980	1988	Low	Mid	High	1980-88	1988-2000[1]
	Thousands					Percent	
Total private							
All occupations	65,812	77,102	78,624	83,655	88,808	2.0	0.7
All science/engineering	1,366	1,858	2,305	2,483	2,650	3.9	2.4
Engineers	992	1,275	1,535	1,659	1,774	3.2	2.2
Aeronautical/astronautical	27	65	88	95	100	11.6	3.2
Chemical	45	45	48	52	55	-0.0	1.1
Civil	79	101	106	114	122	3.1	1.0
Electrical/electronics	273	413	532	575	616	5.3	2.8
Industrial	133	125	152	165	177	-0.8	2.3
Mechanical	198	208	251	271	290	0.6	2.2
Other[2]	237	318	360	388	414	3.7	1.7
Scientists	374	583	770	824	875	5.7	2.9
Life	19	34	35	37	39	7.5	0.9
Mathematical	45	81	102	109	117	7.5	2.5
Physical	108	121	117	125	130	1.4	0.2
Social	26	27	32	35	36	0.3	2.3
Computer specialists	175	321	484	518	552	7.9	4.1
Goods-producing							
All occupations	25,658	25,250	23,412	25,159	26,865	-0.2	-0.0
All science/engineering	852	1,054	1,220	1,325	1,419	2.7	1.9
Engineers	686	829	980	1,066	1,142	2.4	2.1
Aeronautical/astronautical	23	56	76	83	87	11.9	3.2
Chemical	33	36	37	40	43	0.8	1.0
Civil	25	17	16	18	19	-4.9	0.3
Electrical/electronics	168	250	306	334	359	5.1	2.4
Industrial	123	109	131	143	154	-1.5	2.3
Mechanical	137	143	172	187	201	0.5	2.3
Other[2]	176	218	242	262	280	2.7	1.5
Scientists	167	225	240	259	276	3.8	1.2
Life	11	20	20	21	22	7.6	0.5
Mathematical	13	17	18	19	22	3.6	1.0
Physical	86	80	71	75	78	-0.9	-0.6
Social	1	1	2	3	3	8.6	6.3
Computer specialists	56	106	130	141	151	8.3	2.4
Durable goods							
All occupations	12,187	11,437	10,686	11,643	12,547	-0.8	0.1
All science/engineering	580	797	961	1,051	1,131	4.1	2.3
Engineers	515	683	827	905	972	3.6	2.4
Aeronautical/astronautical	23	56	76	83	87	11.9	3.2
Chemical	6	8	9	10	10	3.6	1.8
Civil	5	7	7	7	8	2.5	0.8
Electrical/electronics	154	239	293	320	344	5.6	2.5
Industrial	107	92	112	123	133	-1.8	2.4
Mechanical	102	114	140	153	165	1.4	2.4
Other[2]	118	167	192	210	226	4.4	1.9
Scientists	65	114	134	147	158	7.4	2.1
Life	1	4	4	4	4	20.7	0.4
Mathematical	10	16	17	18	20	6.8	1.0
Physical	17	14	14	15	16	-2.7	0.7
Social	1	1	1	1	1	3.8	0.9
Computer specialists	36	80	99	109	117	10.3	2.6

(continued)

Appendix table 3-1. (Continued)

Industry	Number of jobs					Annual rate of change	
			Projected 2000				
	1980	1988	Low	Mid	High	1980-88	1988-2000[1]
	Thousands					Percent	
Nondurable goods							
All occupations	8,098	7,967	7,206	7,624	8,005	-0.2	-0.4
All science/engineering	166	184	200	213	225	1.3	1.2
Engineers	90	97	109	116	122	0.8	1.5
Aeronautical/astronautical	0	0	0	0	0	[3]	[3]
Chemical	27	27	28	29	31	-0.2	0.9
Civil	1	2	2	2	2	3.2	0.2
Electrical/electronics	5	7	8	9	9	2.9	2.4
Industrial	16	15	17	19	20	-0.6	1.6
Mechanical	24	24	27	29	31	-0.2	1.7
Other[2]	17	23	27	29	30	4.0	2.0
Scientists	75	87	91	97	102	1.9	0.8
Life	10	16	17	17	18	6.4	0.5
Mathematical	3	1	1	1	2	-14.7	1.1
Physical	47	48	46	49	51	0.2	0.1
Social	0	0	0	1	1	[3]	[3]
Computer specialists	15	22	27	29	31	4.9	2.3
Mining							
All occupations	1,027	721	572	598	621	-4.3	-1.6
All science/engineering	55	48	33	33	33	-1.6	-3.0
Engineers	29	27	19	19	20	-1.1	-2.5
Aeronautical/astronautical	0	0	0	0	0	[3]	[3]
Chemical	1	1	0	0	0	6.0	[3]
Civil	1	1	1	1	1	2.8	-2.7
Electrical/electronics	2	1	1	1	1	-10.6	-2.4
Industrial	0	1	0	0	0	[3]	[3]
Mechanical	1	2	1	1	1	2.1	-2.6
Other[2]	24	21	16	16	16	-1.2	-2.5
Scientists	26	22	14	14	14	-2.1	-3.6
Life	0	0	0	0	0	[3]	[3]
Mathematical	0	0	0	0	0	[3]	[3]
Physical	21	18	11	11	11	-2.0	-4.2
Social	0	0	1	1	1	[3]	[3]
Computer specialists	4	3	2	2	2	-3.0	-2.6
Construction							
All occupations	4,346	5,125	4,948	5,294	5,692	2.1	0.3
All science/engineering	53	25	26	28	30	-8.9	1.1
Engineers	52	24	25	26	28	-9.3	0.8
Aeronautical/astronautical	0	0	0	0	0	[3]	[3]
Chemical	0	1	1	1	1	[3]	0.8
Civil	18	8	7	8	9	-9.9	0.3
Electrical/electronics	7	4	4	5	5	-6.9	1.7
Industrial	0	1	1	1	1	[3]	1.2
Mechanical	10	4	4	4	5	-11.3	1.3
Other[2]	17	7	7	8	8	-10.7	0.7
Scientists	1	1	1	2	2	2.4	4.4
Life	0	0	0	0	0	[3]	[3]
Mathematical	0	0	0	0	0	[3]	[3]
Physical	0	0	0	0	0	[3]	[3]
Social	0	0	0	1	1	[3]	[3]
Computer specialists	1	1	1	2	2	2.4	2.0

(continued)

Appendix table 3-1. (Continued)

Industry	Number of jobs					Annual rate of change	
			Projected 2000				
	1980	1988	Low	Mid	High	1980-88	1988-2000[1]
	Thousands					Percent	
Services-producing							
All occupations	40,154	51,852	55,212	58,496	61,944	3.2	1.0
All science/engineering	514	804	1,085	1,158	1,230	5.8	3.1
Engineers	306	446	555	593	632	4.8	2.4
Aeronautical/astronautical	4	9	12	12	13	10.1	2.8
Chemical	12	9	11	11	12	-2.9	1.6
Civil	54	84	90	96	103	5.7	1.1
Electrical/electronics	105	163	226	241	257	5.7	3.3
Industrial	10	16	20	22	23	6.3	2.5
Mechanical	61	65	78	84	89	0.8	2.2
Other[2]	61	100	118	126	134	6.3	2.0
Scientists	207	359	530	565	599	7.1	3.9
Life	8	14	15	16	17	7.3	1.4
Mathematical	32	64	84	89	95	8.8	2.8
Physical	23	41	46	50	52	7.9	1.6
Social	25	25	30	32	34	-0.0	2.1
Computer specialists	119	215	354	377	401	7.6	4.8
Communications/transportation/utilities							
All occupations	5,146	5,548	5,213	5,548	5,904	0.9	0.0
All science/engineering	95	112	124	132	140	2.1	1.4
Engineers	82	79	83	88	93	-0.4	0.9
Aeronautical/astronautical	1	1	1	1	1	-7.6	1.5
Chemical	1	1	1	1	1	1.0	1.2
Civil	5	7	6	7	7	4.4	-0.9
Electrical/electronics	43	39	44	46	49	-1.1	1.4
Industrial	4	5	5	5	6	0.9	0.9
Mechanical	7	6	6	6	6	-3.0	0.5
Other[2]	20	21	21	22	24	0.4	0.5
Scientists	13	32	41	44	46	12.2	2.6
Life	0	1	1	1	1	[3]	2.2
Mathematical	1	2	2	2	2	8.3	-0.4
Physical	0	2	2	2	2	[3]	-0.7
Social	0	2	2	2	2	[3]	1.9
Computer specialists	11	26	35	37	39	10.7	3.1
Trade							
All occupations	20,310	25,138	25,911	27,551	29,201	2.7	0.8
All science/engineering	66	77	105	114	122	1.9	3.3
Engineers	40	41	55	59	63	0.4	3.0
Aeronautical/astronautical	0	0	0	0	0	[3]	[3]
Chemical	3	1	1	1	1	-10.8	1.9
Civil	0	0	0	0	0	[3]	[3]
Electrical/electronics	16	16	22	23	25	-0.2	3.3
Industrial	0	0	0	0	0	[3]	[3]
Mechanical	18	12	16	17	18	-4.7	2.8
Other[2]	3	12	16	17	18	17.3	2.8
Scientists	26	36	51	55	59	4.0	3.6
Life	0	2	2	2	3	[3]	1.6
Mathematical	0	0	0	0	0	[3]	[3]
Physical	1	3	3	3	3	16.8	1.3
Social	0	0	0	1	1	[3]	[3]
Computer specialists	25	32	46	49	53	2.9	3.8

(continued)

Appendix table 3-1. (Continued)

Industry	Number of jobs					Annual rate of change	
			Projected 2000				
	1980	1988	Low	Mid	High	1980-88	1988-2000[1]
	Thousands					Percent	
Financial services							
All occupations	5,160	6,676	7,461	7,864	8,339	3.3	1.4
All science/engineering	52	122	165	174	185	11.3	3.0
Engineers	5	15	20	21	22	13.9	2.8
Aeronautical/astronautical	0	0	0	0	0	[3]	[3]
Chemical	0	0	0	0	0	[3]	[3]
Civil	0	0	0	0	0	[3]	[3]
Electrical/electronics	0	0	0	0	0	[3]	[3]
Industrial	0	0	0	0	0	[3]	[3]
Mechanical	0	0	0	0	0	[3]	[3]
Other[2]	5	15	20	21	22	13.9	2.8
Scientists	46	107	145	154	163	11.0	3.1
Life	0	0	0	0	0	[3]	[3]
Mathematical	16	35	43	45	48	9.9	2.2
Physical	0	0	0	0	0	[3]	[3]
Social	2	7	9	9	10	17.6	2.0
Computer specialists	28	65	94	99	105	11.1	3.6
Business and related services							
All occupations	9,538	14,490	16,628	17,533	18,500	5.4	1.6
All science/engineering	301	494	691	738	784	6.4	3.4
Engineers	179	310	398	426	454	7.1	2.7
Aeronautical/astronautical	3	8	11	12	12	13.9	2.9
Chemical	9	8	9	9	10	-1.6	1.6
Civil	49	77	84	90	96	5.8	1.3
Electrical/electronics	46	108	161	172	183	11.3	4.0
Industrial	5	11	15	16	17	9.6	3.0
Mechanical	35	47	57	61	65	3.5	2.2
Other[2]	32	52	62	66	70	6.0	2.0
Scientists	122	183	292	312	330	5.3	4.5
Life	7	11	12	13	13	5.1	1.3
Mathematical	15	27	39	42	45	7.6	3.8
Physical	22	37	42	45	47	6.8	1.7
Social	23	17	20	21	22	-4.1	1.9
Computer specialists	54	92	179	192	204	6.8	6.3

[1] As projected in the mid scenario.

[2] The "other" engineering category includes a number of smaller fields that are combined in this report due to space limitations. None of these fields individually accounts for more than about 5 percent of the total engineering jobs.

[3] Base number is 0 or too small to estimate.

Notes: Detail may not add to total due to rounding. Percentages are calculated from unrounded data. Macroeconomic assumptions for the low, mid and high scenarios are described in appendix table 3-1a. The standard industrial classification codes are:

Goods-producing	
Durable goods	24, 25, 32-39
Nondurable goods	20-23, 26-31
Mining	10-14
Construction	15-17
Services-producing	
Communications/transportation/utilities	40-49
Trade	50-59
Financial services	60-67
Business and related services	70-79, 81, 83,89

SOURCE: NSF, Division of Science Resources Studies.

See figures 3-2, 3-3, 3-4, 3-5, 3-6, 3-17, 3-18, 3-19, 3-20, 3-21, and 3-22; and O-8 in Overview.

Appendix table 3-1a. Summary statistics for macroeconomic scenarios: 1988-2000

Indicator	Low	Mid	High
	Macroeconomic scenarios		
	Average annual real growth		
	Percent		
GNP	1.8	2.3	2.8
Consumption	1.5	1.9	2.4
Business fixed investment	2.6	3.5	4.5
Exports	4.8	5.7	6.4
Imports	3.0	3.6	4.3
	Average annual growth		
	Percent		
Labor force	0.7	1.2	1.6
Productivity	1.3	1.4	1.6
Industrial production	2.2	2.9	3.5
	Average level		
	Percent		
Inflation (GNP deflator)	6.2	5.0	4.2
Unemployment	5.9	5.6	5.4

Notes: Growth rates for the projection period are compound annual growth rates calculated between the years 1988 and 2000. Level variables are averages for the years 1989 to 2000.

SOURCES: NSF and Data Resources (DRI).

Science & Engineering Indicators—1989

Appendix table 3-2. Scientists and engineers employed in S/E jobs, by field and gender: 1976-88

Field and gender	1976	1978	1980	1982	1984	1986	1988 (est.)
Total scientists and engineers	2,122,100	2,364,400	2,542,700	2,866,700	3,465,100	3,919,900	4,615,500
Men	1,947,200	2,153,000	2,269,900	2,552,500	3,070,400	3,393,700	NA
Women	174,900	211,300	272,800	314,200	394,600	526,200	NA
Total scientists	843,800	937,500	1,032,800	1,147,500	1,402,900	1,676,400	2,000,000
Men	689,100	753,800	806,200	887,700	1,078,200	1,242,800	NA
Women	154,700	183,700	226,600	259,900	324,700	433,600	NA
Physical scientists	154,900	168,200	166,300	210,500	234,000	264,900	286,500
Men	143,600	155,700	151,700	190,000	208,000	229,500	NA
Women	11,300	12,500	14,500	20,500	26,000	35,400	NA
Mathematical scientists	43,800	48,000	57,300	68,300	87,000	103,900	132,500
Men	33,700	36,700	42,100	45,500	68,200	78,900	NA
Women	10,000	11,400	15,200	22,800	18,800	25,000	NA
Computer specialists	116,000	171,400	196,700	216,100	340,400	437,200	551,800
Men	95,100	131,300	147,600	158,700	251,600	308,700	NA
Women	20,900	40,000	49,100	57,400	88,800	128,400	NA
Environmental scientists	46,600	56,900	63,100	82,700	89,900	97,300	98,200
Men	44,000	51,600	54,700	71,100	80,800	87,200	NA
Women	2,600	5,300	8,400	11,700	9,100	10,100	NA
Life scientists	198,200	227,800	267,300	298,000	294,100	340,500	380,800
Men	167,700	191,800	218,400	239,000	226,000	257,100	NA
Women	30,500	36,000	48,900	59,000	68,100	83,300	NA
Psychologists	103,700	107,400	112,500	105,600	151,900	172,800	229,200
Men	71,600	71,100	70,400	66,400	92,900	99,500	NA
Women	32,000	36,300	42,100	39,300	59,000	73,300	NA
Social scientists	180,500	157,800	169,700	166,200	205,600	259,800	321,000
Men	133,200	115,700	121,300	117,000	150,800	181,800	NA
Women	47,300	42,200	48,300	49,200	54,900	78,000	NA
Total engineers	1,278,300	1,426,900	1,509,900	1,719,100	2,062,200	2,243,500	2,615,500
Men	1,258,100	1,399,300	1,463,600	1,664,800	1,992,200	2,150,900	NA
Women	20,200	27,700	46,200	54,300	70,000	92,600	NA
Astronautical/aeronautical	55,700	61,100	65,000	77,200	91,800	104,200	112,000
Men	55,100	60,400	63,700	75,100	89,600	100,300	NA
Women	600	700	1,300	2,100	2,200	3,900	NA
Chemical	76,400	81,900	89,000	101,100	127,500	131,500	132,200
Men	73,700	79,300	84,500	95,300	119,200	121,200	NA
Women	2,800	2,500	4,500	5,700	8,300	10,300	NA
Civil	182,800	205,200	217,000	243,700	293,000	319,100	311,200
Men	178,100	201,900	211,500	237,900	284,400	307,200	NA
Women	4,800	3,300	5,500	5,900	8,500	11,900	NA
Electrical/electronics	267,900	327,000	357,400	413,500	475,000	540,800	601,500
Men	266,500	323,600	350,200	405,400	463,800	523,200	NA
Women	1,400	3,500	7,200	8,100	11,200	17,600	NA
Mechanical	272,800	296,500	308,800	334,400	414,000	453,700	597,900
Men	270,600	292,300	302,000	327,700	403,300	440,100	NA
Women	2,200	4,200	6,800	6,700	10,700	13,600	NA
Other engineers	422,700	455,200	472,700	549,200	660,900	694,200	860,700
Men	414,100	441,800	451,700	523,400	631,900	658,900	NA
Women	8,400	13,500	20,900	25,800	29,100	35,300	NA

NA = Not available; S/E = science and engineering.

Notes: Detail may not add to total because of rounding. Total fields for 1988 were estimated based on the 1988 S/E employment rate for that year. Rates were not available by gender.

SOURCES: NSF, U.S. Scientists and Engineers: 1986; and unpublished data.

See figures 3-7 and 3-8, and O-9 and O-10 in Overview.

Science & Engineering Indicators—1989

Appendix table 3-3. Scientists and engineers employed in non-S/E jobs, by field and gender: 1976-88

Field and gender	1976	1978	1980	1982	1984	1986	1988 (est.)
Total scientists and engineers	209,100	245,400	317,700	386,400	530,400	706,600	859,100
Men	184,400	214,600	274,900	311,600	412,500	534,100	NA
Women	24,800	30,900	42,800	74,700	118,000	172,400	NA
Total scientists	115,700	133,500	151,700	258,200	378,500	509,900	624,800
Men	92,200	103,800	111,800	187,400	265,100	343,900	NA
Women	23,500	29,700	39,900	70,700	113,400	166,000	NA
Physical scientists	34,000	40,100	48,900	16,900	20,100	23,500	24,900
Men	29,100	34,100	42,800	15,100	17,800	20,600	NA
Women	4,900	6,000	6,300	1,800	2,300	2,900	NA
Mathematical scientists	4,800	5,700	7,000	11,100	13,400	27,100	34,800
Men	3,400	3,800	4,300	8,500	10,300	18,200	NA
Women	1,500	1,700	2,800	2,500	3,100	8,900	NA
Computer specialists	3,000	5,600	11,100	82,900	96,400	125,400	158,400
Men	3,300	5,500	2,300	61,600	71,100	91,300	NA
Women	0	200	8,800	21,300	25,300	34,100	NA
Environmental scientists	8,200	12,000	14,500	4,500	8,200	14,000	14,400
Men	6,900	10,100	12,100	3,700	7,000	11,200	NA
Women	1,300	1,900	2,300	700	1,200	2,800	NA
Life scientists	15,300	16,300	20,200	39,100	59,200	71,300	79,600
Men	11,900	12,700	16,000	29,500	44,700	51,900	NA
Women	3,400	3,600	4,200	9,600	14,500	19,500	NA
Psychologists	8,800	14,300	15,600	32,800	57,600	80,700	104,900
Men	5,300	8,600	9,000	16,600	28,200	38,900	NA
Women	3,600	5,700	6,600	16,100	29,400	41,900	NA
Social scientists	41,800	39,600	34,300	71,000	123,600	168,000	207,800
Men	32,500	28,900	25,400	52,300	86,000	112,000	NA
Women	9,300	10,600	8,900	18,700	37,500	56,000	NA
Total engineers	93,400	111,900	166,000	128,100	151,900	196,600	234,300
Men	92,200	110,700	163,100	124,200	147,400	190,200	NA
Women	1,200	1,100	3,000	4,000	4,500	6,400	NA
Astronautical/aeronautical	1,100	900	4,500	3,600	5,400	6,300	6,600
Men	1,300	1,000	4,600	3,600	5,300	5,900	NA
Women	0	0	0	0	0	400	NA
Chemical	1,100	2,300	5,500	6,600	12,600	17,500	17,400
Men	1,300	2,400	5,500	6,300	12,100	16,600	NA
Women	0	0	0	400	500	900	NA
Civil	5,400	6,500	15,100	14,500	19,700	27,200	26,700
Men	4,700	6,500	14,800	14,300	19,000	26,200	NA
Women	600	0	300	200	800	1,000	NA
Electrical/electronics	15,100	14,500	25,700	24,200	25,700	33,700	37,700
Men	14,900	14,400	25,200	23,200	24,700	32,300	NA
Women	200	0	400	1,000	1,000	1,300	NA
Mechanical	3,400	2,800	13,800	23,500	31,600	38,900	51,300
Men	3,300	2,900	14,000	23,100	31,300	38,500	NA
Women	100	0	0	400	300	400	NA
Other engineers	67,300	84,900	101,400	55,700	56,900	73,000	94,600
Men	66,800	83,600	98,900	53,700	55,000	70,700	NA
Women	700	1,200	2,600	2,000	1,900	2,400	NA

NA = Not available; S/E = science and engineering.

Note: Detail may not add to total because of rounding. Total fields for 1988 were estimated based on the 1988 S/E employment rate for that year. Rates were not available by gender.

SOURCES: NSF, U.S. Scientists and Engineers: 1986; estimated and unpublished data.

See figure 3-7.

Appendix table 3-4. Scientists and engineers employed in S/E jobs, by field and racial/ethnic group: 1976-88

Field and racial/ethnic group	1976	1978	1980	1982	1984	1986	1988 (est.)
Total scientists and engineers	2,122,100	2,364,400	2,542,700	2,866,700	3,465,100	3,919,900	4,615,500
White	1,949,700	2,189,600	2,349,700	2,638,200	3,159,500	3,556,200	NA
Black	34,900	43,000	50,900	59,000	73,600	87,900	NA
Asian	98,500	102,800	112,000	122,500	169,400	199,000	NA
Other	39,000	29,000	30,100	47,000	62,600	76,800	NA
Total scientists	843,800	937,500	1,032,800	1,147,500	1,402,900	1,676,400	2,000,000
White	764,200	868,500	957,900	1,058,300	1,281,900	1,521,000	NA
Black	19,400	23,200	26,000	30,000	39,000	50,600	NA
Asian	43,100	35,700	37,500	40,700	57,500	72,300	NA
Other	17,100	10,100	11,400	18,500	24,500	32,500	NA
Physical scientists	154,900	168,200	166,300	210,500	234,000	264,900	286,500
White	141,200	157,600	155,600	197,700	213,100	240,400	NA
Black	2,400	2,500	2,400	2,900	4,800	5,400	NA
Asian	6,400	7,300	7,100	7,400	11,500	14,500	NA
Other	4,900	800	1,200	2,500	4,600	4,600	NA
Mathematical scientists	43,800	48,000	57,300	68,300	87,000	103,900	132,500
White	39,400	44,100	52,600	61,800	76,300	91,300	NA
Black	2,500	2,400	2,500	3,400	4,400	6,100	NA
Asian	1,700	1,500	2,100	2,500	4,500	4,200	NA
Other	200	0	100	600	1,800	2,300	NA
Computer specialists	116,000	171,400	196,700	216,100	340,400	437,200	551,800
White	108,000	159,100	181,500	196,000	305,000	388,200	NA
Black	1,500	3,200	4,300	6,200	9,900	13,200	NA
Asian	3,900	8,200	9,700	10,400	20,800	27,600	NA
Other	2,600	900	1,200	3,500	4,700	8,200	NA
Environmental scientists	46,600	56,900	63,100	82,700	89,900	97,300	98,200
White	40,700	51,600	57,700	76,700	56,100	93,600	NA
Black	1,800	1,000	800	400	600	400	NA
Asian	2,900	1,600	2,000	3,600	1,700	1,900	NA
Other	1,200	2,700	2,600	2,000	31,500	1,400	NA
Life scientists	198,200	227,800	267,300	298,000	294,100	340,500	380,800
White	186,100	213,200	250,700	280,400	273,800	313,100	NA
Black	4,700	5,300	6,400	7,500	5,400	7,100	NA
Asian	5,400	6,300	6,900	6,500	9,300	12,900	NA
Other	2,000	3,000	3,300	3,600	5,600	7,400	NA
Psychologists	103,700	107,400	112,500	105,600	151,900	172,800	229,200
White	97,100	102,400	107,400	100,700	143,000	161,800	NA
Black	3,700	3,400	3,400	2,400	5,100	6,000	NA
Asian	700	700	1,000	1,000	1,400	1,400	NA
Other	2,200	900	700	1,500	2,400	3,600	NA
Social scientists	180,500	157,800	169,700	166,200	205,600	259,800	321,000
White	151,600	140,500	152,600	145,100	184,700	232,600	NA
Black	2,900	5,500	6,400	7,200	8,900	12,300	NA
Asian	22,100	10,300	8,700	9,300	8,100	9,700	NA
Other	3,900	1,500	2,000	4,600	3,900	5,200	NA

(continued)

Appendix table 3-4. (Continued)

Field and racial/ethnic group	1976	1978	1980	1982	1984	1986	1988 (est.)
Total engineers	1,278,300	1,426,900	1,509,900	1,719,100	2,062,200	2,243,500	2,615,500
White	1,185,500	1,321,100	1,391,700	1,579,800	1,877,600	2,035,200	NA
Black	15,500	19,800	24,900	29,000	34,500	37,300	NA
Asian	55,400	67,100	74,600	81,700	112,000	126,700	NA
Other	21,900	18,900	18,700	28,600	38,100	44,300	NA
Astronautical/aeronautical	55,700	61,100	65,000	77,200	91,800	104,200	112,000
White	52,900	56,800	60,500	72,700	86,000	94,900	NA
Black	300	1,000	1,200	1,100	1,000	1,400	NA
Asian	1,700	2,100	2,100	2,600	4,100	6,500	NA
Other	800	1,200	1,200	800	700	1,400	NA
Chemical	76,400	81,900	89,000	101,100	127,500	131,500	132,200
White	71,100	76,000	81,300	91,800	113,700	119,200	NA
Black	1,500	300	400	900	1,200	900	NA
Asian	2,400	4,000	5,700	6,800	10,000	9,200	NA
Other	1,400	1,600	1,600	1,600	2,600	2,200	NA
Civil	182,800	205,200	217,000	243,700	293,000	319,100	311,200
White	162,500	185,000	194,900	218,500	258,100	284,300	NA
Black	1,800	2,700	3,800	3,600	4,500	4,800	NA
Asian	14,800	14,500	15,200	16,500	23,000	23,300	NA
Other	3,700	3,000	3,100	5,100	7,400	6,700	NA
Electrical/electronics	267,900	327,000	357,400	413,500	475,000	540,800	601,500
White	248,800	297,900	323,600	375,100	424,800	481,800	NA
Black	2,600	5,700	7,500	8,800	10,600	11,000	NA
Asian	12,700	19,500	22,100	23,100	29,400	36,000	NA
Other	3,800	3,900	4,200	6,500	10,200	12,000	NA
Mechanical	272,800	296,500	308,800	334,400	414,000	453,700	597,900
White	255,300	277,400	288,900	310,800	382,300	416,000	NA
Black	2,200	2,100	2,500	3,400	4,500	6,400	NA
Asian	9,600	12,800	13,600	14,600	20,000	23,400	NA
Other	5,700	4,200	3,800	5,600	7,200	7,900	NA
Other engineers	422,700	455,200	472,700	549,200	660,900	694,200	860,700
White	394,900	428,000	442,500	510,900	612,700	639,000	NA
Black	7,100	8,000	9,500	11,200	12,700	12,800	NA
Asian	14,200	14,200	15,900	18,100	25,500	28,300	NA
Other	6,500	5,000	4,800	9,000	10,000	14,100	NA

NA = Not available; S/E = science and engineering.

Notes: Detail may not add to total because of rounding. Total fields for 1988 were estimated based on the 1988 S/E employment rate for that year. Rates were not available by racial/ethnic group.

SOURCES: NSF, U.S. Scientists and Engineers: 1986; estimates and unpublished data.

See figure 3-9.

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Appendix table 3-5. Employed doctoral scientists and engineers, by field and gender: 1977-87

Field and gender	1977	1979	1981	1983	1985	1987
Total scientists and engineers	285,055	314,257	343,956	369,320	400,358	419,118
Men	257,465	280,857	302,971	320,494	341,873	352,386
Women	27,590	33,400	40,985	48,826	58,485	66,732
Total scientists	240,005	263,915	286,917	307,775	334,505	351,350
Men	212,696	231,040	246,685	260,025	277,508	286,346
Women	27,309	32,875	40,232	47,750	56,997	65,004
Physical scientists	57,531	60,222	63,110	63,986	67,480	68,647
Men	54,594	57,086	59,346	59,811	62,809	63,163
Women	2,937	3,136	3,764	4,175	4,671	5,484
Mathematical scientists	14,609	15,250	15,569	16,379	16,758	16,699
Men	13,560	14,104	14,259	14,964	15,199	15,074
Women	1,049	1,146	1,310	1,415	1,559	1,625
Computer specialists	5,767	6,684	9,064	12,164	14,964	18,571
Men	5,534	6,318	8,363	10,898	13,345	16,693
Women	233	366	701	1,266	1,619	1,878
Environmental scientists	13,001	14,575	15,909	16,467	17,288	17,811
Men	12,560	13,968	15,054	15,553	16,199	16,510
Women	441	607	855	914	1,089	1,301
Life scientists	70,537	78,857	84,912	92,802	101,838	107,378
Men	61,437	67,528	71,593	76,573	82,146	85,269
Women	9,100	11,329	13,319	16,229	19,692	22,109
Psychologists	33,652	37,848	42,829	46,645	52,182	56,378
Men	26,055	28,690	31,103	32,962	35,573	37,274
Women	7,597	9,158	11,726	13,683	16,609	19,104
Social scientists	44,908	50,479	55,524	59,332	63,995	65,866
Men	38,956	43,346	46,967	49,264	52,237	52,363
Women	5,952	7,133	8,557	10,068	11,758	13,503
Total engineers	45,050	50,342	57,039	61,545	65,853	67,768
Men	44,769	49,817	56,286	60,469	64,365	66,040
Women	281	525	753	1,076	1,488	1,728
Astronautical/aeronautical	1,987	2,364	2,519	3,684	3,827	5,005
Men	1,967	2,340	2,480	3,614	3,732	4,884
Women	20	24	39	70	95	121
Chemical	5,603	6,166	7,146	6,992	7,122	6,923
Men	5,575	6,117	7,092	6,895	7,021	6,783
Women	28	49	54	97	101	140
Civil	4,066	5,157	6,089	5,317	6,396	6,479
Men	4,051	5,101	6,003	5,245	6,305	6,316
Women	15	56	86	72	91	163
Electrical/electronics	8,284	8,597	10,630	12,696	14,248	12,601
Men	8,246	8,528	10,493	12,460	13,901	12,236
Women	38	69	137	236	347	365
Mechanical	4,648	5,245	5,370	5,657	6,594	6,711
Men	4,629	5,213	5,330	5,603	6,536	6,613
Women	19	32	40	54	58	98
Other engineers	20,462	22,813	25,285	27,199	27,666	30,049
Men	20,301	22,518	24,888	26,652	26,870	29,208
Women	161	295	397	547	796	841

Note: Detail may not add to total because of rounding.

SOURCE: NSF, Characteristics of Doctoral Scientists and Engineers in the United States: 1987.

See figure 3-10.

Appendix table 3-6. Employed doctoral scientists and engineers, by field and racial/ethnic group: 1977-87

Field and racial/ethnic group	1977	1979	1981	1983	1985	1987
Total scientists and engineers	285,055	314,257	343,953	369,320	400,358	419,118
White	258,255	284,965	309,123	328,455	355,125	372,985
Black	2,709	3,227	4,224	4,948	5,716	6,359
Asian	16,275	22,912	27,350	29,740	34,533	36,397
Other	7,816	3,153	3,256	6,177	4,984	3,377
Total scientists	240,005	263,915	286,917	307,775	334,505	351,350
White	219,636	243,008	261,912	278,722	302,526	319,091
Black	2,588	3,125	3,954	4,538	5,203	5,704
Asian	11,229	15,037	18,328	19,259	22,651	23,645
Other	6,552	2,745	2,723	5,256	4,125	2,910
Physical scientists	57,531	60,222	63,110	63,986	67,480	68,647
White	51,963	54,618	56,245	56,521	59,598	60,751
Black	543	403	579	690	522	620
Asian	3,441	4,719	5,769	5,684	6,561	6,788
Other	1,584	482	517	1,091	799	488
Mathematical scientists	14,609	15,250	15,569	16,379	16,758	16,699
White	13,218	13,729	13,975	14,531	14,921	14,940
Black	120	144	167	178	166	166
Asian	799	1,110	1,155	1,378	1,368	1,482
Other	472	267	272	292	303	111
Computer specialists	5,767	6,684	9,064	12,164	14,964	18,571
White	5,014	6,059	8,056	11,012	13,064	16,219
Black	15	4	27	43	85	200
Asian	613	561	868	944	1,634	1,838
Other	125	60	113	165	181	314
Environmental scientists	13,001	14,575	15,909	16,467	17,288	17,811
White	12,125	13,813	14,996	15,476	15,774	16,587
Black	24	65	34	33	98	222
Asian	572	539	744	770	1,133	943
Other	280	158	135	188	283	59
Life scientists	70,537	78,857	84,912	92,802	101,838	107,378
White	64,243	71,861	77,089	83,378	92,002	96,955
Black	769	883	1,013	1,142	1,419	1,456
Asian	3,980	5,417	6,257	6,750	7,412	8,207
Other	1,545	696	553	1,532	1,005	760
Psychologists	33,652	37,848	42,829	46,645	52,182	56,378
White	31,943	36,480	9,825	44,237	49,508	53,655
Black	467	594	809	983	1,190	1,266
Asian	313	412	583	640	756	858
Other	929	362	31,612	785	728	599
Social scientists	44,908	50,479	55,524	59,332	63,995	65,866
White	41,130	46,448	50,542	53,567	57,659	59,984
Black	650	1,032	1,325	1,469	1,723	1,774
Asian	1,511	2,279	2,952	3,093	3,787	3,529
Other	1,617	720	705	1,203	826	579

(continued)

Appendix table 3-6. (Continued)

Field and racial/ethnic group	1977	1979	1981	1983	1985	1987
Total engineers	45,050	50,342	57,039	61,545	65,853	67,768
White	38,619	41,957	47,211	49,733	52,599	53,894
Black	121	102	270	410	513	655
Asian	5,046	7,875	9,022	10,481	11,882	12,752
Other	1,264	408	536	921	859	467
Astronautical/aeronautical	1,987	2,364	2,519	3,684	3,827	5,005
White	1,793	2,122	2,232	3,128	3,295	4,092
Black	0	2	10	21	27	34
Asian	138	232	269	482	503	869
Other	56	8	8	53	2	10
Chemical	5,603	6,166	7,146	6,992	7,122	6,923
White	4,674	4,953	5,553	5,384	5,130	4,988
Black	12	10	37	13	66	72
Asian	721	1,200	1,554	1,502	1,923	1,814
Other	196	3	2	93	3	49
Civil	4,066	5,157	6,089	5,317	6,396	6,479
White	3,255	3,875	4,785	4,190	5,063	5,182
Black	5	1	24	24	85	23
Asian	718	1,204	1,226	1,059	1,182	1,254
Other	88	77	54	44	66	20
Electrical/electronics	8,284	8,597	10,630	12,696	14,248	12,601
White	7,229	7,252	8,931	10,310	11,386	9,744
Black	45	15	40	75	90	209
Asian	833	1,272	1,552	2,093	2,553	2,525
Other	177	58	107	218	219	123
Mechanical	4,648	5,245	5,370	5,657	6,594	6,711
White	3,793	4,057	4,313	4,382	5,069	5,124
Black	5	22	10	91	81	127
Asian	771	1,165	1,045	1,157	1,354	1,412
Other	79	1	2	27	90	48
Other engineers	20,462	22,813	25,285	27,199	27,666	30,049
White	17,875	19,698	21,397	22,339	22,656	24,764
Black	54	52	149	186	164	190
Asian	1,865	2,802	3,376	4,188	4,367	4,878
Other	668	261	363	486	479	217

Note: Detail may not add to total because of rounding.

SOURCE: NSF, Characteristics of Doctoral scientists and Engineers in the United States: 1987.

See figure 3-11.

Science & Engineering Indicators—1989

Appendix table 3-7. Selected employment characteristics of scientists and engineers, by field, gender, and racial/ethnic group: 1986

Field and racial/ethnic group	Labor force participation rate			Unemployment rate			S/E employment rate			S/E underemployment rate			S/E underutilization rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent														
Total scientists & engineers[1]	94.5	94.6	93.9	1.5	1.3	2.7	84.7	86.4	75.3	2.6	1.9	6.3	4.1	3.2	8.9
White	94.3	94.4	93.8	1.5	1.3	2.6	84.9	86.4	75.9	2.5	1.9	6.1	3.9	3.1	8.5
Black	97.2	97.6	96.4	3.8	2.8	6.0	76.5	79.1	70.2	5.5	3.7	9.7	9.1	6.4	15.2
Asian	96.3	97.0	93.1	1.8	1.9	1.6	87.7	90.7	72.0	2.2	1.8	4.1	3.9	3.6	5.6
Native American	96.0	95.9	96.8	1.2	1.3	(3)	79.3	80.5	69.4	2.4	1.1	13.1	3.6	2.4	13.1
Hispanic[2]	95.2	96.1	92.2	2.1	2.2	1.7	80.2	83.8	66.5	4.8	2.5	13.4	6.7	4.6	14.8
Total scientists	95.3	95.9	94.0	1.9	1.6	2.7	76.7	78.3	72.3	4.3	3.3	7.0	6.1	4.8	9.5
White	95.2	95.8	93.8	1.8	1.5	2.6	77.1	78.6	73.0	4.2	3.3	6.7	5.9	4.7	9.1
Black	97.0	97.2	96.7	3.7	1.6	6.5	68.7	69.7	67.2	7.5	5.2	10.8	10.9	6.7	16.7
Asian	96.1	97.5	93.2	2.3	2.8	1.1	76.9	81.7	66.3	3.5	3.0	4.6	5.8	5.8	5.7
Native American	96.6	96.7	96.4	2.1	2.7	(3)	68.2	68.5	67.3	5.0	2.1	14.7	7.0	4.8	14.7
Hispanic[2]	94.9	96.5	91.9	3.0	3.8	1.4	67.5	71.0	61.2	8.2	4.0	15.9	10.9	7.6	17.0
Physical scientists	93.6	94.1	90.8	1.4	1.2	3.1	91.9	91.8	92.4	1.9	1.6	3.5	3.3	2.8	6.5
White	93.5	94.0	90.2	1.4	1.1	3.1	91.8	91.6	93.4	1.7	1.5	3.0	3.1	2.7	6.0
Black	98.1	98.4	97.6	2.6	2.0	4.2	87.2	89.3	81.8	4.6	3.1	8.5	7.1	5.0	12.3
Asian	93.0	93.5	91.9	1.2	1.3	0.9	94.4	94.8	93.5	2.5	2.2	3.3	3.6	3.4	4.1
Native American	80.7	80.7	(3)	(3)	(3)	(3)	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	94.1	97.3	83.1	3.2	1.3	10.7	96.8	96.7	97.4	1.8	1.7	2.6	5.0	3.0	13.0
Mathematical scientists	94.6	95.4	92.6	1.3	0.8	2.7	79.3	81.3	73.8	3.3	2.0	7.1	4.6	2.8	9.6
White	94.2	95.0	92.1	1.3	0.7	2.7	79.0	81.2	73.0	3.1	1.8	6.8	4.3	2.5	9.3
Black	98.4	98.4	98.5	1.2	(3)	3.4	90.0	90.5	89.0	4.2	5.5	1.8	5.4	5.5	5.1
Asian	97.9	98.4	94.8	2.3	2.6	(3)	70.3	69.3	77.0	3.9	3.3	7.5	6.1	5.9	7.5
Native American	100.0	100.0	100.0	(3)	(3)	(3)	39.7	66.7	13.8	44.0	(3)	86.2	44.0	(3)	86.2
Hispanic[2]	97.6	97.7	97.4	0.9	1.4	(3)	82.6	92.3	67.0	3.6	1.5	6.9	4.4	2.9	6.9
Computer specialists	98.5	99.4	96.5	0.8	0.6	1.6	77.7	77.2	79.0	2.5	2.5	2.5	3.3	3.0	4.0
White	98.6	99.4	96.6	0.8	0.5	1.6	78.1	77.5	79.7	2.4	2.4	2.2	3.2	3.0	3.8
Black	99.2	100.0	98.0	1.2	0.3	2.7	70.1	69.8	70.6	4.2	2.7	6.6	5.4	3.0	9.2
Asian	97.6	99.3	92.7	0.6	0.5	1.0	76.6	76.9	75.5	2.7	2.5	3.4	3.3	3.0	4.3
Native American	100.0	100.0	100.0	1.9	2.2	(3)	52.4	47.8	75.4	(3)	(3)	(3)	1.9	2.2	(3)
Hispanic[2]	96.4	100.0	89.3	0.9	1.3	(3)	65.7	69.9	56.5	5.5	6.6	3.1	6.3	7.8	3.1

(continued)

Appendix table 3-7. (Continued)

Field and racial/ethnic group	Labor force participation rate			Unemployment rate			S/E employment rate			S/E underemployment rate			S/E underutilization rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent														
Environmental scientists	94.5	94.8	92.1	4.4	3.9	8.2	87.4	88.6	78.6	5.6	4.8	11.6	9.7	8.5	18.8
White	94.4	94.7	91.9	4.5	4.0	8.4	88.5	89.8	78.5	5.5	4.6	11.7	9.7	8.4	19.1
Black	97.5	97.1	100.0	0.6	0.2	2.8	41.3	31.9	100.0	4.4	5.1	(3)	5.0	5.4	2.8
Asian	97.3	97.1	100.0	2.6	2.9	(3)	89.6	91.2	71.7	8.8	9.7	(3)	11.2	12.2	(3)
Native American	93.8	93.0	100.0	(3)	(3)	(3)	74.2	77.9	50.0	15.5	10.2	50.0	15.5	10.2	50.0
Hispanic[2]	95.0	94.5	100.0	4.8	5.3	(3)	84.5	85.4	76.6	9.0	8.9	9.6	13.3	13.7	9.6
Life scientists	93.0	94.1	90.0	2.1	1.7	3.4	82.7	83.2	81.1	4.7	3.1	9.6	6.7	4.7	12.6
White	92.8	93.9	89.5	2.1	1.6	3.4	82.9	83.1	82.1	4.4	3.1	8.5	6.4	4.7	11.6
Black	98.5	98.8	97.9	3.8	1.4	7.4	80.9	83.4	76.9	7.3	3.4	13.7	10.9	4.8	20.1
Asian	94.0	96.1	90.7	2.6	2.1	3.3	85.7	90.4	77.6	7.5	3.2	14.7	9.9	5.2	17.5
Native American	100.0	100.0	100.0	(3)	(3)	(3)	63.3	75.3	41.5	0.7	(3)	2.0	0.7	(3)	2.0
Hispanic[2]	92.2	94.2	89.5	0.8	1.3	(3)	71.3	74.6	66.5	16.2	5.7	31.5	16.9	6.9	31.5
Psychologists	95.1	94.9	95.3	2.5	2.2	3.0	68.2	71.9	63.6	5.7	4.7	6.8	8.1	6.8	9.6
White	95.0	94.7	95.4	2.3	1.8	3.0	69.1	71.7	65.7	5.8	4.8	7.0	8.0	6.6	9.8
Black	94.5	97.0	93.3	3.6	1.5	4.6	66.6	80.4	59.3	4.9	(3)	7.5	8.3	1.5	11.7
Asian	99.0	100.0	98.8	4.3	23.0	(3)	28.0	95.2	16.2	(3)	(3)	(3)	4.3	23.0	(3)
Native American	100.0	100.0	100.0	8.5	11.2	(3)	94.3	92.3	100.0	11.5	(3)	44.6	19.1	11.2	44.6
Hispanic[2]	96.1	96.3	95.9	4.3	4.8	3.8	46.3	40.9	51.0	7.1	5.3	8.7	11.1	9.8	12.2
Social scientists	95.4	95.8	94.6	2.4	2.3	2.7	60.7	61.9	58.2	7.2	5.4	11.1	9.4	7.5	13.6
White	95.3	95.8	94.3	2.0	2.0	2.1	61.1	62.3	58.1	6.9	5.2	10.9	8.8	7.1	12.8
Black	95.0	93.7	96.8	6.8	3.4	11.2	53.7	50.8	57.8	13.1	9.8	17.9	19.0	12.8	27.1
Asian	96.1	97.8	92.9	6.4	9.6	(3)	68.4	74.7	57.0	3.0	4.3	0.5	9.2	13.5	0.5
Native American	95.0	100.0	81.1	(3)	(3)	(3)	49.0	34.0	100.0	7.5	9.7	(3)	7.5	9.7	(3)
Hispanic[2]	95.0	95.6	93.8	5.8	8.7	(3)	57.6	57.9	56.9	7.7	0.6	20.9	13.1	9.2	20.9
Total engineers	93.8	93.8	93.6	1.2	1.2	2.5	91.9	91.9	93.5	1.0	1.0	2.3	2.2	2.1	4.8
White	93.5	93.5	93.5	1.2	1.1	2.5	91.8	91.7	93.5	1.0	0.9	2.4	2.1	2.0	4.9
Black	97.7	98.0	94.8	4.0	4.2	2.0	90.3	90.2	90.9	2.0	1.9	2.3	5.8	6.0	4.3
Asian	96.5	96.7	93.0	1.5	1.4	3.7	95.4	95.4	94.7	1.2	1.1	1.9	2.7	2.5	5.5
Native American	95.6	95.5	100.0	0.4	0.4	(3)	87.8	87.8	87.5	0.4	0.5	(3)	0.9	0.9	(3)
Hispanic[2]	95.6	95.8	93.4	1.2	1.0	3.2	92.6	92.5	93.5	1.4	1.5	0.8	2.6	2.5	4.0

(continued)

Appendix table 3-7. (Continued)

Field and racial/ethnic group	Labor force participation rate			Unemployment rate			S/E employment rate			S/E underemployment rate			S/E underutilization rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent														
Aeronautical/ astronautical	94.7	94.5	98.7	0.4	0.4	1.3	94.3	94.4	91.1	0.6	0.5	3.5	1.0	0.9	4.8
White	94.3	94.1	98.6	0.5	0.4	1.4	94.2	94.3	91.0	0.4	0.3	3.1	0.9	0.7	4.5
Black	100.0	100.0	100.0	(3)	(3)	(3)	86.4	87.3	75.7	7.6	6.3	24.3	7.6	6.3	24.3
Asian	99.6	99.6	100.0	(3)	(3)	(3)	98.2	98.1	100.0	0.8	0.8	(3)	0.8	0.8	(3)
Native American	86.7	86.7	(3)	(3)	(3)	(3)	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	100.0	100.0	100.0	(3)	(3)	(3)	92.9	92.5	100.0	6.0	6.4	(3)	6.0	6.4	(3)
Chemical	89.1	89.1	89.8	2.6	2.5	4.0	88.2	87.9	92.3	1.9	1.8	3.2	4.5	4.3	7.1
White	88.6	88.6	89.1	2.6	2.5	3.6	89.1	88.7	94.1	1.8	1.8	2.3	4.3	4.2	5.8
Black	99.0	100.0	94.3	1.9	0.9	6.6	43.6	40.7	59.0	6.2	3.4	21.0	8.0	4.3	26.2
Asian	95.8	96.1	93.5	4.2	3.7	8.6	91.3	91.9	86.3	1.7	1.4	4.2	5.9	5.1	12.5
Native American	74.9	74.1	100.0	(3)	(3)	(3)	10.9	7.1	100.0	6.8	7.1	(3)	6.8	7.1	(3)
Hispanic[2]	99.7	99.6	100.0	6.8	7.7	2.2	92.0	93.8	83.7	0.6	0.7	(3)	7.3	8.4	(3)
Civil	92.3	92.2	95.0	1.7	1.6	3.6	92.1	92.1	92.4	1.2	1.0	6.3	2.9	2.6	9.7
White	92.1	92.0	94.7	1.3	1.3	3.2	92.1	92.1	91.4	1.3	1.0	7.1	2.6	2.3	10.0
Black	98.3	98.6	90.4	17.2	17.7	5.7	91.7	91.3	100.0	1.3	1.2	2.4	18.2	18.6	8.0
Asian	93.3	93.1	97.9	1.3	1.1	6.3	95.2	95.0	100.0	0.7	0.7	(3)	1.9	1.8	6.3
Native American	97.9	97.9	(3)	(3)	(3)	(3)	95.7	95.7	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	92.2	92.5	87.9	2.0	0.7	20.9	97.3	97.2	100.0	1.7	1.8	(3)	3.6	2.5	20.9
Electrical/ electronics	93.5	93.7	90.0	1.1	1.1	1.0	94.1	94.2	93.0	0.8	0.8	0.3	1.8	1.8	1.3
White	93.2	93.3	90.9	1.0	1.0	0.7	94.1	94.1	92.8	0.7	0.8	(3)	1.7	1.8	0.7
Black	96.1	97.5	73.2	3.1	3.3	(3)	92.1	91.8	100.0	2.0	2.1	(3)	5.1	5.3	(3)
Asian	96.5	97.3	85.5	1.3	1.1	4.5	95.1	95.3	92.7	0.7	0.6	2.8	2.0	1.7	7.1
Native American	94.6	94.6	(3)	(3)	(3)	(3)	90.4	90.4	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	94.5	95.0	84.9	1.4	1.5	(3)	93.4	94.0	80.1	0.3	0.3	(3)	1.7	1.8	(3)

(continued)

Appendix table 3-7. (Continued)

Field and racial/ethnic group	Labor force participation rate			Unemployment rate			S/E employment rate			S/E underemployment rate			S/E underutilization rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent														
Industrial	96.1	96.0	97.0	1.1	1.1	1.4	82.2	81.6	91.6	1.2	1.1	3.0	2.3	2.2	4.3
White	95.8	95.8	96.7	1.1	1.1	1.6	81.3	80.8	91.1	1.1	1.0	2.8	2.2	2.1	4.3
Black	100.0	100.0	100.0	1.9	2.4	(3)	93.4	91.7	100.0	4.9	6.2	(3)	6.7	8.4	(3)
Asian	100.0	100.0	100.0	1.5	1.6	(3)	96.5	97.4	81.3	1.1	(3)	18.7	2.6	1.6	18.7
Native American	100.0	100.0	100.0	(3)	(3)	(3)	100.0	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	95.0	95.9	74.0	(3)	(3)	(3)	93.1	92.9	100.0	4.0	4.2	(3)	4.0	4.2	(3)
Materials	94.0	94.1	92.7	1.7	0.7	17.4	88.3	88.1	92.0	0.9	0.9	0.8	2.6	1.6	18.0
White	93.8	93.8	93.2	1.7	0.7	20.5	87.8	87.3	99.0	0.8	0.8	1.0	2.4	1.4	21.3
Black	99.0	100.0	97.1	0.3	0.5	(3)	72.4	100.0	16.1	(3)	(3)	(3)	0.3	0.5	(3)
Asian	95.6	97.0	77.0	2.3	2.0	6.9	97.1	97.0	100.0	3.4	3.6	(3)	5.6	5.5	6.9
Native American	100.0	100.0	100.0	(3)	(3)	(3)	100.0	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	96.3	93.3	100.0	0.5	1.0	(3)	96.1	92.8	100.0	(3)	(3)	(3)	0.5	1.0	(3)
Mechanical	91.2	91.1	93.2	1.3	1.3	2.5	92.1	92.0	96.5	1.1	1.1	1.8	2.4	2.4	4.3
White	90.7	90.7	92.5	1.3	1.3	2.5	91.9	91.8	96.6	1.0	1.0	1.9	2.3	2.3	4.3
Black	97.4	97.1	100.0	1.2	0.6	6.4	95.6	95.9	93.0	0.6	0.7	(3)	1.8	1.2	6.4
Asian	97.1	97.0	100.0	1.8	1.9	(3)	95.3	95.2	100.0	2.5	2.5	(3)	4.2	4.3	(3)
Native American	100.0	100.0	(3)	(3)	(3)	(3)	89.0	89.0	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	94.7	94.6	100.0	0.2	0.2	-3.0	87.3	87.2	90.3	1.4	1.2	9.7	1.6	1.3	9.7
Mining	93.7	93.6	96.0	2.2	2.2	1.0	86.1	85.6	97.6	1.6	1.6	0.7	3.8	3.8	1.7
White	94.1	94.0	95.7	2.2	2.2	1.0	85.7	85.2	97.4	1.6	1.6	0.8	3.7	3.8	1.8
Black	4.8	4.8	(3)	(3)	(3)	(3)	(3)	(3)	(3)	100.0	100.0	(3)	100.0	100.0	(3)
Asian	97.9	97.9	(3)	(3)	(3)	(3)	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Native American	100.0	100.0	(3)	64.3	64.3	(3)	100.0	100.0	(3)	(3)	(3)	(3)	64.3	64.3	(3)
Hispanic[2]	100.0	100.0	100.0	6.9	9.6	(3)	100.0	100.0	100.0	(3)	(3)	(3)	6.9	9.6	(3)
Nuclear	97.8	98.1	89.0	1.0	1.0	1.4	97.5	97.5	98.1	0.4	0.3	0.5	1.4	1.4	1.8
White	97.7	98.1	88.4	1.0	1.0	0.8	97.4	97.4	97.9	0.3	0.3	0.5	1.3	1.3	1.4
Black	98.9	98.8	100.0	1.4	(3)	17.2	100.0	100.0	100.0	(3)	(3)	(3)	1.4	(3)	17.2
Asian	98.7	98.9	76.9	0.5	0.5	(3)	99.2	99.2	100.0	0.6	0.6	(3)	1.1	1.1	(3)
Native American	100.0	100.0	(3)	(3)	(3)	(3)	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	95.7	100.0	81.0	2.2	2.7	(3)	85.2	81.7	100.0	2.3	2.8	(3)	4.4	5.5	(3)

(continued)

Appendix table 3-7. (Continued)

Field and racial/ethnic group	Labor force participation rate			Unemployment rate			S/E employment rate			S/E underemployment rate			S/E underutilization rate		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent														
Petroleum	95.3	95.3	95.2	3.4	3.2	6.9	92.9	93.5	84.6	2.0	1.9	4.4	5.4	5.0	11.0
White	95.6	95.6	96.0	3.0	2.7	7.6	92.7	93.0	86.4	2.2	2.0	5.0	5.1	4.6	12.2
Black	98.2	98.1	100.0	5.5	5.9	(3)	92.2	100.0	(3)	(3)	(3)	(3)	5.5	5.9	(3)
Asian	72.5	68.5	83.3	5.5	7.9	(3)	90.1	100.0	70.0	(3)	(3)	(3)	5.5	7.9	(3)
Native American	92.0	91.9	100.0	(3)	(3)	(3)	100.0	100.0	100.0	(3)	(3)	(3)	(3)	(3)	(3)
Hispanic[2]	87.1	85.9	100.0	1.4	1.6	(3)	98.7	98.6	100.0	1.3	1.4	(3)	2.7	3.0	(3)
Other engineers	98.3	98.4	96.4	0.7	0.6	0.8	92.7	92.6	95.0	0.8	0.8	1.5	1.5	1.4	2.4
White	98.2	98.3	96.0	0.6	0.5	0.9	92.4	92.4	94.2	0.8	0.8	1.8	1.4	1.3	2.7
Black	99.2	99.0	100.0	0.4	0.5	(3)	93.7	92.3	100.0	0.9	1.1	(3)	1.3	1.6	(3)
Asian	99.2	99.3	98.2	0.7	0.6	1.2	96.5	96.3	98.7	0.8	0.9	(3)	1.5	1.5	1.2
Native American	100.0	100.0	100.0	1.6	1.7	(3)	94.4	95.4	72.9	(3)	(3)	(3)	1.6	1.7	(3)
Hispanic[2]	99.1	99.5	95.8	0.0	0.0	(3)	92.3	91.4	100.0	1.6	1.7	(3)	1.6	1.8	(3)

[1] Detail will not add to total because racial and ethnic categories are not mutually exclusive and total employed includes other and no report.

[2] Includes members of all racial groups.

[3] Too few cases to estimate.

SOURCE: NSF, U.S. Scientist and Engineers: 1986.

See figures 3-12 and 3-13.

Appendix table 3-8. Scientists and engineers as a percentage of total U.S. workforce: 1976-88

	Percent
1976	2.4
1978	2.5
1980	2.6
1982	2.9
1984	3.3
1986	3.6
1988	4.1

SOURCES: NSF, U.S. Scientists and Engineers: 1988; Council of Economic Advisers, *Economic Report of the President*, (Washington, DC: Government Printing Office, 1989), p. 347.

See figure 3-8.

Science & Engineering Indicators—1989

Appendix table 3-9. Number of 1984 and 1985 science and engineering degree recipients working as computer specialists in 1986, by field

	Bachelor's		Master's	
Field	1984	1985	1984	1985
	Number			
Total	35,600	41,900	8,000	8,800
Physical sciences	700	200	100	100
Mathematics	3,900	3,600	400	400
Computer science	24,200	29,800	6,000	6,800
Engineering	3,700	3,100	1,200	1,100
Environmental sciences	100	100	100	100
Life sciences	400	400	[1]	100
Social sciences	1,900	4,000	200	200
Psychology	600	600	[1]	100

[1] Too few cases to report.

Note: Detail may not add to totals due to rounding.

Source: NSF, *Characteristics of Recent Science and Engineering Graduates: 1986*, NSF 87-321 (Washington, DC: NSF, 1987).

See figure 3-15.

Science & Engineering Indicators—1989

Appendix table 3-10. Selected employment characteristics of recent S/E bachelor's and master's degree recipients, by field and gender: 1986

Field and gender	Labor force participation rate		Unemployment rate		S/E employment rate	
	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's
Total science and engineering	98.1	97.9	3.5	2.1	63.8	84.3
Men	98.6	99.0	3.4	1.7	69.9	86.8
Women	97.2	95.2	3.7	3.2	52.9	77.6
Total sciences	97.6	97.3	3.9	2.6	52.6	78.6
Men	98.0	98.9	4.0	2.2	56.1	81.1
Women	97.1	94.8	3.9	3.3	48.5	74.5
Physical sciences	97.0	96.4	2.0	1.4	68.0	85.7
Men	98.1	99.2	2.0	1.4	71.6	85.7
Women	95.6	(2)	2.1	(2)	62.8	(2)
Chemistry	95.3	97.7	2.7	1.3	75.5	90.9
Men	96.1	(2)	2.3	(2)	78.6	(2)
Women	94.6	(2)	3.1	(2)	72.3	(2)
Physics/astronomy	98.6	(2)	2.4	(2)	80.2	(2)
Men	100.0	(2)	2.8	(2)	78.8	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Other physical sciences	100.0	(2)	0.2	(2)	39.1	(2)
Men	100.0	(2)	0.2	(2)	46.7	(2)
Women	100.0	(2)	0.1	(2)	29.2	(2)
Mathematics/statistics	98.0	97.6	1.9	1.5	73.6	89.7
Men	98.2	99.4	2.3	1.4	71.4	88.9
Women	97.7	94.5	1.6	1.6	75.7	91.1
Computer science	99.7	98.4	2.7	0.4	89.2	90.0
Men	99.6	99.0	2.9	0.3	88.7	89.5
Women	99.8	96.6	2.5	0.9	89.9	91.6
Environmental sciences	97.9	98.6	4.4	6.1	60.8	92.5
Men	98.0	99.6	4.7	5.8	60.9	93.8
Women	97.6	(2)	3.2	(2)	60.5	(2)
Life sciences	95.8	97.4	4.9	4.2	56.7	80.6
Men	96.6	98.8	3.8	4.0	60.7	82.3
Women	94.9	96.0	6.1	4.4	52.6	78.9
Biology	94.7	97.5	6.2	4.0	51.1	77.9
Men	95.0	99.6	4.9	5.0	53.1	76.2
Women	94.5	95.9	7.3	3.2	49.5	79.2
Agricultural sciences	98.0	97.2	2.3	4.6	67.8	85.7
Men	99.0	97.8	2.4	2.7	71.2	89.8
Women	96.2	(2)	2.2	(2)	61.9	(2)
Psychology	95.6	96.5	5.3	4.4	26.1	67.3
Men	98.5	(2)	8.4	(2)	28.0	(2)
Women	94.3	94.7	3.8	2.9	25.2	69.6
Social sciences	98.0	96.0	4.4	3.4	30.5	55.8
Men	97.4	97.8	4.4	2.6	32.8	57.8
Women	98.8	94.0	4.4	4.4	27.5	53.2
Economics	100.0	94.2	5.8	3.5	39.6	57.7
Men	100.0	94.7	5.7	2.7	37.9	49.8
Women	100.0	(2)	6.1	(2)	43.9	(2)
Sociology/anthropology	96.0	94.8	10.9	4.9	31.0	39.6
Men	96.7	(2)	10.0	(2)	33.2	(2)
Women	95.5	95.0	11.5	7.0	29.4	47.7

(continued)

Appendix table 3-10. (Continued)

Field and gender	Labor force participation rate		Unemployment rate		S/E employment rate	
	Bachelor's	Master's	Bachelor's	Master's	Bachelor's	Master's
Other social sciences	97.2	97.4	0.6	2.8	23.5	60.6
Men	94.9	100.0	1.2	3.1	27.4	68.5
Women	100.0	93.7	(1)	2.4	19.2	48.9
Total engineering	99.3	99.0	2.4	1.2	89.1	94.6
Men	99.5	99.1	2.4	1.0	89.3	94.2
Women	97.7	97.9	1.9	2.8	88.2	97.6
Aeronautical/astronautical	99.1	(2)	1.9	(2)	86.0	(2)
Men	99.0	(2)	2.1	(2)	87.5	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Chemical	98.9	99.0	3.2	3.3	85.8	94.8
Men	99.7	98.8	3.4	1.9	86.2	94.7
Women	96.7	(2)	2.9	(2)	84.8	(2)
Civil	99.5	98.5	2.3	1.0	92.7	95.5
Men	99.7	99.0	2.5	0.4	92.1	95.7
Women	97.9	(2)	1.1	(2)	96.6	(2)
Electrical/electronics	99.1	99.7	2.0	(1)	91.9	96.8
Men	99.4	99.7	2.1	(1)	92.2	96.5
Women	96.2	(2)	1.3	(2)	89.5	(2)
Industrial	98.9	99.9	0.4	2.3	87.3	83.3
Men	100.0	(2)	0.5	(2)	88.8	(2)
Women	95.2	(2)	(1)	(2)	81.8	(2)
Materials	96.7	(2)	2.2	(2)	88.9	(2)
Men	96.8	(2)	1.5	(2)	87.5	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Mechanical	100.0	99.7	2.6	1.3	90.3	96.5
Men	100.0	99.7	2.6	1.4	89.7	96.6
Women	100.0	(2)	2.8	(2)	95.6	(2)
Mining	97.5	(2)	5.7	(2)	81.8	(2)
Men	97.0	(2)	6.6	(2)	83.7	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Nuclear	(2)	(2)	(2)	(2)	(2)	(2)
Men	(2)	(2)	(2)	(2)	(2)	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Petroleum	100.0	(2)	8.5	(2)	88.3	(2)
Men	100.0	(2)	7.2	(2)	90.4	(2)
Women	(2)	(2)	(2)	(2)	(2)	(2)
Other engineering	99.1	97.4	2.2	2.1	81.2	90.4
Men	99.1	97.7	2.5	2.1	80.8	89.2
Women	99.5	(2)	0.4	(2)	83.8	(2)

S/E = Science and engineering.

[1] No unemployment reported.

[2] No rate computed for groups with less than 1500 in labor force.

Note: Combined 1984/1985 graduates, exclusive of full-time graduate students.

SOURCE: NSF, *Characteristics of Recent Science and Engineering Graduates: 1986*, NSF 87-321 (Washington, DC: NSF, 1987).

See figure 3-14.

Science & Engineering Indicators—1989

Appendix table 3-11. High Technology Recruitment Index: 1961-89

	Index
	(1961 = 100)
1961	100
1962	120
1963	98
1964	88
1965	132
1966	159
1967	124
1968	98
1969	86
1970	60
1971	44
1972	63
1973	97
1974	101
1975	69
1976	88
1977	115
1978	140
1979	145
1980	139
1981	136
1982	104
1983	102
1984	134
1985	113
1986	109
1987	117
1988	113
1989[1]	103

[1] Second quarter data.

SOURCES: NSF, Deutsch, Shea, and Evans, *High Technology Recruitment Index Year End Review and Forecast* (New York, 1983); and unpublished data.

See figure 3-16.

Science & Engineering Indicators—1989

Appendix table 3-12. Selected data on stock and flows of the S/E workforce, by occupational group or field of degree: 1986

	Total scientists and engineers		Natural scientists, engineers, and computer specialists		Social and behavioral scientists	
	Number	Percent	Number	Percent	Number	Percent
Status of 1985 S/E employed workers in 1986						
Total 1985	3,514	100.0	3,136	100.0	378	100.0
Employed in S/E	3,229	91.9	2,875	91.7	354	93.8
Deceased	28	0.8	26	0.8	3	0.7
Unemployed	11	0.3	17	0.5	[1]	[1]
Emigrated	15	0.4	12	0.4	4	1.0
Employed in non-S/E	132	3.8	119	3.8	13	3.5
Out of workforce	99	2.8	89	2.8	10	2.6
Source of 1986 S/E employed workers						
Total 1986	3,682	100.0	3,275	100.0	407	100.0
1985 S/E employed carryover to 1986	3,229	87.7	2,875	87.8	354	87.1
Total 1985 S/E graduates	227	6.2	196	6.0	31	7.6
U.S. citizens	210	5.7	180	5.5	30	7.3
Foreign citizens	17	0.5	16	0.5	1	0.3
Re-entrants to S/E employment	172	4.7	152	4.6	20	4.9
Direct immigration	30	0.8	28	0.9	1	0.3
Upgraded workers	24	24	0			
Workforce status of S/E graduates by broad field of study[2]						
Total	327	100.0	225	100.0	102	100.0
Employed in S/E	210	64.2	180	80.0	30	31.6
Employed in non-S/E	101	30.8	36	15.9	65	68.4
Out of workforce	10	3.0	5	2.2	5	5.3
Unemployed	6	2.0	4	2.0	2	2.1

S/E = Science and engineering.

[1] There was a net reduction of 6 in S/E unemployment.

[2] Excluding full-time graduate students.

Notes: Data rounded to nearest thousand and percentages are based on unrounded data. See text footnotes for definitions of methodology and caveats.

SOURCE: NSF, Division of Science Resources Studies.

See figure 3-23.

Appendix table 3-13. Nonacademic scientists and engineers per 10,000 labor force for selected countries, by gender: most current years

	France (1982)	West Germany (1985)	Japan (1985)	United Kingdom (1981)	United States (1986)
	Numbers of scientists and engineers				
Scientists and engineers	387,860	621,500	1,514,200	585,190	3,583,300
Male	346,020	585,400	1,444,400	533,380	3,103,100
Female	41,840	36,100	69,800	51,810	480,200
Scientists	139,980	114,100	389,900	219,740	1,393,000
Male	107,100	95,700	338,400	173,880	1,032,200
Female	32,880	18,400	51,500	45,860	360,800
Engineers	247,880	507,400	1,124,300	365,450	2,190,400
Male	238,920	489,700	1,106,000	359,500	2,100,600
Female	8,960	17,700	18,300	5,950	89,800
	Scientists and engineers per 10,000 labor force				
Scientists and engineers	163	223	254	219	300
Male	146	210	242	199	260
Female	18	13	12	19	40
Scientists	59	41	65	82	117
Male	45	34	57	65	86
Female	14	7	9	17	30
Engineers	104	182	189	137	183
Male	101	176	185	134	176
Female	4	6	3	2	8
Labor force	23,743,000	27,844,000	59,634,000	26,740,000	119,540,000

Notes: The number of scientists and engineers for France, West Germany, Japan, and the United Kingdom are estimates prepared by the U.S. Bureau of the Census based on published and unpublished census and survey data for the years shown. United Kingdom data excludes Northern Ireland. Figures refer to scientists and engineers employed in S/E jobs. Figures may not sum due to rounding. Data by gender for the United States are estimates. Labor force data are from the Organisation For Economic Co-operation and Development; thus, the number of scientists and engineers per 10,000 labor force differs from data published in the Bureau of the Census reports cited below.

SOURCES: Figures for West Germany, Japan, and the United Kingdom are from U.S. Bureau of the Census, Center for International Research, "Recent Data on Scientists and Engineers in Industrialized Countries" (Washington, DC, 1988). Data for France are from P.O. Way and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, 1986). U.S. figures are from NSF.

See figure 3-24.

Science & Engineering Indicators—1989

Appendix table 3-14. Scientists and engineers in manufacturing for selected countries, by occupation group: most current years

Occupation	France (1982)	West Germany (1985)	Japan (1980)	United Kingdom (1981)	United States (1986)
			Percent		
Total scientists & engineers . . .	100.0	100.0	100.0	100.0	100.0
Scientists	22.9	18.0	18.1	27.0	18.8
Natural	9.2	12.6	4.5	12.3	9.5
Computer	12.4	(1)	13.5	14.1	9.2
Social	1.2	5.4	NA	0.6	0.1
Engineers	77.1	82.0	81.9	73.0	81.2
Civil	3.5	3.2	1.6	1.3	0.9
Electrical/electronic	20.5	21.9	24.5	12.6	25.2
Industrial/mechanical	53.1	56.8	55.9	59.0	55.1

Note: NA = Not available.

[1] Systems analysts are included with natural scientists; computer engineers are included with electrical/electronic engineers.

Notes: Figures for France, West Germany, Japan, and the United Kingdom are estimates prepared by the U.S. Bureau of the Census based on published and unpublished census and survey data for the years shown. United Kingdom data exclude Northern Ireland. Figures refer to scientists and engineers employed in S/E jobs. Figures may not sum because of rounding.

SOURCES: Figures for West Germany, Japan, and the United Kingdom are from U.S. Bureau of the Census, Center for International Research, "Recent Data on Scientists and Engineers in Industrialized Countries" (Washington, DC, 1988). Data for France are from P.O. Way and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, 1986). U.S. figures are from NSF.

See figure 3-25.

Science & Engineering Indicators—1989

Appendix table 3-15. Nonacademic scientists and engineers in selected countries, by sector of employment: most current years

Sector	France (1982)	West Germany (1985)	Japan (1985)	United Kingdom (1981)	United States (1986)
			Scientists		
			Percent		
Total	100.0	100.0	100.0	100.0	100.0
Agriculture	0.4	0.2	NA	0.5	0.9
Mining	2.0	(1)	NA	1.3	3.0
Manufacturing	14.1	43.0	8.4	31.8	19.8
Construction	0.5	0.9	0.7	0.7	0.1
Wholesale and retail trade	2.9	2.2	0.1	4.8	3.8
Transportation, communications, and public utilities	1.5	2.9	NA	5.5	3.0
Services	41.8	39.7	89.3	45.3	45.6
Government	36.8	7.4	1.4	10.1	24.0
All other	NA	3.7	NA	0.1	NA
			Engineers		
			Percent		
Total	100.0	100.0	100.0	100.0	100.0
Agriculture	(2)	0.1	0.4	0.1	0.1
Mining	3.7	(1)	0.3	2.0	2.3
Manufacturing	30.9	43.9	30.7	52.4	53.1
Construction	7.9	10.5	18.2	9.7	3.2
Wholesale and retail trade	2.6	1.9	3.9	2.4	2.7
Transportation, communications,, and public utilities	7.0	10.1	5.3	10.7	5.4
Services	20.9	21.0	37.3	17.0	20.9
Government	26.9	12.0	3.9	5.7	12.3
All other	NA	0.5	NA	0.0	NA

[1] Data for mining are included under transportation, communications, and public utilities.

[2] Less than 0.05 percent.

Notes: Figures for France, West Germany, Japan, and the United Kingdom are estimates prepared by the U.S. Bureau of the Census based on published and unpublished census and survey data for the years shown. United Kingdom data exclude Northern Ireland. Figures refer to scientists and engineers employed in science and engineering jobs.

SOURCES: Figures for West Germany, Japan, and the United Kingdom are from U.S. Bureau of the Census, Center for International Research, "Recent Data on Scientists and Engineers in Industrialized Countries" (Washington, DC, 1988). Data for France are from P.O. Way and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, 1986). U.S. figures are from NSF.

See figure 3-26.

Science & Engineering Indicators—1989

Appendix table 3-16. Scientists and engineers engaged in R&D for selected countries: 1965-87

	France	West Germany	Japan	United Kingdom	United States
			Thousands		
1965	42.8	61.0	117.6	49.9	494.6
1966	60.0	60.0	128.9	NA	521.1
1967	52.4	64.5	138.7	NA	534.4
1968	54.7	68.0	157.6	52.8	550.4
1969	57.2	74.9	157.1	NA	553.2
1970	58.5	82.5	172.0	NA	544.2
1971	60.1	90.2	194.3	NA	523.8
1972	61.2	96.0	198.1	76.7	515.3
1973	62.7	101.0	226.6	NA	514.8
1974	64.1	102.5	238.2	NA	520.8
1975	65.3	103.7	255.2	80.5	527.7
1976	67.0	104.5	260.2	NA	535.6
1977	68.0	111.0	272.0	NA	561.0
1978	70.9	113.9	273.1	87.7	587.0
1979	72.9	116.9	281.9	NA	614.8
1980	74.9	120.7	302.6	NA	651.7
1981	85.5	124.7	317.5	95.7	683.7
1982	90.1	127.7	329.7	NA	702.8
1983	92.7	130.8	342.2	94.1	722.9
1984	98.2	137.1	370.0	96.3	746.3
1985	102.3	143.6	381.3	98.0	772.5
1986	105.1	146.6	405.6	98.7	802.3
1987	108.2	151.5	418.3	NA	NA

NA = Not available.

Notes: Table includes all scientists and engineers engaged in R&D on a full-time basis except (1) Japan, whose data include persons primarily employed in R&D in the natural sciences and engineering; and (2) the United Kingdom, whose data include only the government and industry sectors. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed in 1977; data starting with 1979 were revised in 1988 using improved methodologies. The figures for France increased in 1981 in part due to a re-evaluation of university research efforts. Data are estimated by NSF for the following countries and years: France, 1986 and 1987; West Germany, 1978, 1980, 1982, 1984, 1986, and 1987; United Kingdom, 1984.

SOURCES: NSF; Organization for Economic Co-operation and Development; and national data.

See figure 3-27.

Science & Engineering Indicators—1989

Appendix table 3-17. Nonacademic scientists and engineers in selected countries, by age group: most current years

Age group	France (1982)	West Germany (1985)	Japan (1985)	United Kingdom (1981)	United States (1986)
	Percent				
Total	100.0	100.0	100.0	100.0	100.0
Under 35 years of age	30.0	30.3	48.5	47.3	32.9
35-54	58.0	56.0	44.9	41.0	49.0
Over 55	12.0	13.6	6.7	11.8	18.1

Notes: Figures for France, West Germany, Japan, and the United Kingdom are estimates prepared by the U.S. Bureau of the Census based on published and unpublished census and survey data for the years shown. United Kingdom data exclude Northern Ireland. Figures refer to scientists and engineers employed in S/E jobs. Figures may not sum because of rounding. U.S. data are for academic and nonacademic scientists and engineers, and exclude those respondents for whom no age was reported.

SOURCES: Figures for West Germany, Japan, and the United Kingdom are from U.S. Bureau of the Census, Center for International Research, "Recent Data on Scientists and Engineers in Industrialized Countries" (Washington, DC, 1988). Data for France are from P.O. Way and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, 1986). U.S. figures are from NSF.

See figure 3-28.

Science & Engineering Indicators—1989

Appendix table 3-18. First university degrees for selected countries, by major field of study: 1986

	France[1]	West Germany	Japan	United Kingdom	United States
	Number of degrees				
All fields	52,728	63,866	376,260	72,000	1,074,785
Natural science and engineering	25,043	21,584	99,668	29,100	213,971
Natural science	11,321	10,766	12,814	17,500	122,170
Engineering	13,722	8,477	73,316	10,300	77,061
Agriculture	([2])	2,341	13,538	1,300	14,740
All others	27,685	42,282	276,592	42,900	860,814
	Percentage distribution among fields				
All fields	100.0	100.0	100.0	100.0	100.0
Natural science and engineering	47.5	33.8	26.5	40.4	19.9
Natural science	21.5	16.9	3.4	24.3	11.4
Engineering	26.0	13.3	19.5	14.3	7.2
Agriculture	([2])	3.7	3.6	1.8	1.4
All others	52.5	66.2	73.5	59.6	80.1
	As a proportion of the 22-year-old population				
All fields	6.1	5.9	22.6	7.4	25.9
Natural science and engineering	2.9	2.0	6.0	3.0	5.2
Natural science	1.3	1.0	0.8	1.8	2.9
Engineering	1.6	0.8	4.4	1.1	1.9
Agriculture	([2])	0.2	0.8	0.1	0.4
All others	3.2	3.9	16.6	4.4	20.7
22-year-old population	871,000	1,088,000	1,668,000	975,000	4,152,000

[1] Data for France are based on maitrise degrees and engineering degrees. French engineering degrees are equivalent to U.S. master's degrees.

[2] Included in natural sciences.

Note: Natural sciences include physical sciences, biological sciences, and mathematics.

SOURCES: U.S. data are from NSF; Japanese, Ministry of Education; West German, Statistisches Bundesamt; U.K., University Grants Committee; and French, Ministry of Education.

See figure O-7 in Overview.

Science & Engineering Indicators—1989

Appendix table 3-19. Scientists and engineers engaged in R&D per 10,000 labor force and total labor force for selected countries: 1965-86

	Scientists and engineers engaged in R&D per 10,000 labor force					Labor force				
	France	West Germany	Japan	United Kingdom	United States	France	West Germany	Japan	United Kingdom	United States
	Percent					Thousands				
1965	21.0	22.6	24.6	19.6	64.7	20,365	27,034	47,870	25,498	76,401
1966	29.2	22.3	26.4	NA	NA	20,534	26,962	48,910	25,632	77,892
1967	25.3	24.4	27.8	NA	NA	20,678	26,409	49,830	25,490	79,565
1968	26.2	25.9	31.1	20.8	67.9	20,861	26,291	50,610	25,378	80,990
1969	27.1	28.2	30.8	NA	66.6	21,095	26,535	50,980	25,375	82,972
1970	27.3	30.8	33.4	NA	64.1	21,415	26,817	51,530	25,308	84,889
1971	27.9	33.4	37.5	NA	60.6	21,578	27,002	51,860	25,207	86,355
1972	28.2	35.6	38.1	30.4	58.0	21,738	26,990	52,000	25,264	88,847
1973	28.5	37.1	42.5	NA	56.4	22,022	27,195	53,260	25,612	91,203
1974	28.8	37.8	44.9	NA	55.6	22,260	27,147	53,100	25,659	93,670
1975	29.2	38.6	47.9	31.1	55.3	22,353	26,884	53,230	25,893	95,453
1976	29.6	39.2	48.4	NA	54.7	22,605	26,651	53,780	26,111	97,826
1977	29.7	41.8	49.9	NA	55.7	22,910	26,577	54,520	26,224	100,665
1978	30.7	42.7	49.4	33.3	56.5	23,062	26,692	55,320	26,357	103,882
1979	31.4	43.4	50.4	NA	57.7	23,243	26,923	55,960	26,628	106,559
1980	32.1	44.3	53.6	NA	60.0	23,369	27,217	56,500	26,840	108,544
1981	36.3	45.5	55.6	35.8	61.9	23,530	27,416	57,070	26,740	110,315
1982	37.9	46.4	57.1	NA	62.8	23,743	27,542	57,740	26,678	111,872
1983	39.1	47.4	58.1	35.4	63.8	23,714	27,589	58,890	26,594	113,226
1984	41.1	49.6	62.4	35.5	64.7	23,867	27,629	59,270	27,090	115,241
1985	42.8	51.6	63.9	35.5	65.9	23,902	27,844	59,634	27,624	117,167
1986	43.8	52.3	67.4	35.5	66.2	24,009	28,024	60,200	27,771	119,540

NA = Not available.

Notes: Table includes all scientists and engineers engaged in R&D on a full-time equivalent basis except Japan, whose data include persons primarily employed in R&D in the natural sciences and engineering and all higher education science and engineering faculty. The United Kingdom data include only the government and industry sectors. The figures for West Germany increased in 1979 partially because of increased coverage of small medium enterprises not surveyed in 1977; starting with 1979, data were revised in 1988 using improved methodologies. The figures for France increased in 1981 in part due to a re-evaluation of university research efforts. Data are NSF estimates for the following countries and years: France, 1986 and 1987; West Germany, 1978, 1980, 1982, 1984 1986, and 1987; United Kingdom, 1984.

SOURCES: NSF; Organization for Economic Co-operation and Development; and national data.

See figure O-6 in Overview.

Science & Engineering Indicators—1989

Appendix table 4-1. GNP implicit price deflators and GNP: 1960-90

	GNP implicit price deflators		GNP	
	Calendar year	Fiscal year	Calendar year	Fiscal year
			—Billions of dollars—	
1960	0.3095	0.3111	515.3	507.8
1961	0.3124	0.3144	533.8	519.0
1962	0.3194	0.3200	574.7	556.7
1963	0.3240	0.3258	606.9	588.6
1964	0.3293	0.3305	649.8	629.4
1965	0.3378	0.3375	705.1	673.6
1966	0.3496	0.3474	772.0	740.5
1967	0.3594	0.3593	816.4	793.6
1968	0.3773	0.3719	892.7	852.4
1969	0.3978	0.3920	964.0	929.5
1970	0.4203	0.4148	1,015.5	990.5
1971	0.4438	0.4366	1,102.7	1,057.1
1972	0.4649	0.4606	1,212.8	1,151.2
1973	0.4954	0.4835	1,359.3	1,285.5
1974	0.5396	0.5216	1,472.8	1,417.0
1975	0.5931	0.5752	1,598.4	1,523.5
1976	0.6307	0.6208	1,782.8	1,699.6
1977	0.6728	0.6703	1,990.5	1,935.8
1978	0.7222	0.7172	2,249.7	2,173.4
1979	0.7857	0.7790	2,508.2	2,452.2
1980	0.8572	0.8474	2,732.0	2,667.7
1981	0.9396	0.9321	3,052.6	2,986.2
1982	1.0000	1.0000	3,166.0	3,141.5
1983	1.0386	1.0423	3,405.7	3,322.4
1984	1.0773	1.0819	3,772.2	3,695.7
1985	1.1095	1.1153	4,014.9	3,950.9
1986	1.1393	1.1458	4,240.3	4,191.1
1987	1.1767	1.1824	4,526.7	4,437.2
1988	1.2120	1.2173	4,826.4	4,740.4
1989	1.2589	1.2638	5,170.2	5,071.8
1990	1.3038	1.3095	5,531.7	5,429.0

Note: Calendar year deflators were taken directly from sources cited below. Fiscal year deflators were calculated from quarterly data in the same sources.

SOURCES: NSF, Division of Science Resources Studies; U.S. Department of Commerce, *Survey of Current Business* and *Commerce News*; Executive Office of the President, Office of Management and Budget.

Science & Engineering Indicators—1989

Appendix table 4-2. R&D, by performer and source: 1960-89

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of current dollars														
1960	13,523	1,726	10,509	6,081	4,428	646	405	40	149	52	360	282	166	48	68
1961	14,316	1,874	10,908	6,240	4,668	763	500	40	165	58	410	361	226	49	86
1962	15,394	2,098	11,464	6,435	5,029	904	613	40	185	66	470	458	295	54	109
1963	17,059	2,279	12,630	7,270	5,360	1,081	760	41	207	73	530	539	365	55	119
1964	18,854	2,838	13,512	7,720	5,792	1,275	917	40	235	83	629	600	433	55	112
1965	20,044	3,093	14,185	7,740	6,445	1,474	1,073	41	267	93	629	663	477	62	124
1966	21,846	3,220	15,548	8,332	7,216	1,715	1,261	42	304	108	630	733	525	70	138
1967	23,146	3,396	16,385	8,365	8,020	1,921	1,409	48	345	119	673	771	552	74	145
1968	24,605	3,494	17,429	8,560	8,869	2,149	1,573	55	390	131	719	814	582	81	151
1969	25,631	3,503	18,308	8,451	9,857	2,225	1,600	60	420	145	725	870	616	93	161
1970	26,134	4,079	18,067	7,779	10,288	2,335	1,648	61	461	165	737	916	649	95	172
1971	26,676	4,228	18,320	7,666	10,654	2,500	1,724	70	529	177	716	912	630	98	184
1972	28,477	4,590	19,552	8,017	11,535	2,630	1,795	74	574	187	753	952	653	101	198
1973	30,718	4,762	21,249	8,145	13,104	2,884	1,985	84	613	202	817	1,006	690	105	211
1974	32,864	4,911	22,887	8,220	14,667	3,023	2,032	96	677	218	865	1,178	822	115	241
1975	35,213	5,354	24,187	8,605	15,582	3,409	2,288	113	749	259	987	1,276	875	125	276
1976	39,018	5,769	26,997	9,561	17,436	3,729	2,512	123	810	284	1,147	1,376	925	135	316
1977	42,783	6,012	29,825	10,485	19,340	4,067	2,726	139	888	314	1,384	1,495	987	150	358
1978	48,129	6,811	33,304	11,189	22,115	4,625	3,059	170	1,037	359	1,717	1,672	1,100	165	407
1979	54,933	7,417	38,226	12,518	25,708	5,361	3,595	194	1,198	374	1,935	1,994	1,350	180	464
1980	62,594	7,632	44,505	14,029	30,476	6,061	4,096	238	1,326	401	2,246	2,150	1,450	200	500
1981	71,866	8,425	51,810	16,382	35,428	6,845	4,561	293	1,555	436	2,486	2,300	1,550	225	525
1982	79,364	9,141	57,995	18,483	39,512	7,324	4,759	339	1,735	491	2,479	2,425	1,650	250	525
1983	87,280	10,582	63,403	20,542	42,861	7,883	4,980	388	1,936	579	2,737	2,675	1,850	275	550
1984	97,793	11,572	71,470	23,162	48,308	8,623	5,425	474	2,107	617	3,118	3,010	2,100	325	585
1985	107,757	12,945	78,269	26,830	51,439	9,694	6,064	559	2,377	694	3,529	3,320	2,300	360	660
1986	112,497	13,535	80,631	27,783	52,848	10,926	6,713	692	2,789	732	3,900	3,505	2,400	410	695
1987 (prel.)	118,782	13,413	85,500	30,000	55,500	12,082	7,326	777	3,145	834	4,202	3,585	2,350	445	790
1988 (est.)	126,115	14,500	90,600	31,500	59,100	13,000	7,800	850	3,470	880	4,400	3,615	2,300	480	835
1989 (est.)	132,350	14,750	95,350	32,750	62,600	13,900	8,250	920	3,800	930	4,650	3,700	2,300	515	885

(continued)

Appendix table 4-2. (Continued)

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of constant 1982 dollars[4]														
1960	43,693	5,577	33,955	19,648	14,307	2,087	1,309	129	481	168	1,163	911	536	155	220
1961	45,826	5,999	34,917	19,974	14,942	2,442	1,601	128	528	186	1,312	1,156	723	157	275
1962	48,197	6,569	35,892	20,147	15,745	2,830	1,919	125	579	207	1,472	1,434	924	169	341
1963	52,651	7,034	38,981	22,438	16,543	3,336	2,346	127	639	225	1,636	1,664	1,127	170	367
1964	57,255	8,618	41,032	23,444	17,589	3,872	2,785	121	714	252	1,910	1,822	1,315	167	340
1965	59,337	9,156	41,992	22,913	19,079	4,364	3,176	121	790	275	1,862	1,963	1,412	184	367
1966	62,489	9,211	44,474	23,833	20,641	4,906	3,607	120	870	309	1,802	2,097	1,502	200	395
1967	64,402	9,449	45,590	23,275	22,315	5,345	3,920	134	960	331	1,873	2,145	1,536	206	403
1968	65,213	9,261	46,194	22,688	23,506	5,696	4,169	146	1,034	347	1,906	2,157	1,543	215	400
1969	64,432	8,806	46,023	21,244	24,779	5,593	4,022	151	1,056	365	1,823	2,187	1,549	234	405
1970	62,179	9,705	42,986	18,508	24,478	5,556	3,921	145	1,097	393	1,754	2,179	1,544	226	409
1971	60,108	9,527	41,280	17,274	24,006	5,633	3,885	158	1,192	399	1,613	2,055	1,420	221	415
1972	61,254	9,873	42,056	17,245	24,812	5,657	3,861	159	1,235	402	1,620	2,048	1,405	217	426
1973	62,006	9,612	42,893	16,441	26,451	5,822	4,007	170	1,237	408	1,649	2,031	1,393	212	426
1974	60,904	9,101	42,415	15,234	27,181	5,602	3,766	178	1,255	404	1,603	2,183	1,523	213	447
1975	59,371	9,027	40,781	14,509	26,272	5,748	3,858	191	1,263	437	1,664	2,151	1,475	211	465
1976	61,865	9,147	42,805	15,159	27,645	5,912	3,983	195	1,284	450	1,819	2,182	1,467	214	501
1977	63,589	8,936	44,330	15,584	28,746	6,045	4,052	207	1,320	467	2,057	2,222	1,467	223	532
1978	66,642	9,431	46,115	15,493	30,622	6,404	4,236	235	1,436	497	2,377	2,315	1,523	228	564
1979	69,916	9,440	48,652	15,932	32,720	6,823	4,576	247	1,525	476	2,463	2,538	1,718	229	591
1980	73,021	8,903	51,919	16,366	35,553	7,071	4,778	278	1,547	468	2,620	2,508	1,692	233	583
1981	76,486	8,967	55,140	17,435	37,705	7,285	4,854	312	1,655	464	2,646	2,448	1,650	239	559
1982	79,364	9,141	57,995	18,483	39,512	7,324	4,759	339	1,735	491	2,479	2,425	1,650	250	525
1983	84,036	10,189	61,047	19,779	41,268	7,590	4,795	374	1,864	557	2,635	2,576	1,781	265	530
1984	90,776	10,742	66,342	21,500	44,842	8,004	5,036	440	1,956	573	2,894	2,794	1,949	302	543
1985	97,122	11,667	70,544	24,182	46,362	8,737	5,466	504	2,142	626	3,181	2,992	2,073	324	595
1986	98,742	11,880	70,772	24,386	46,386	9,590	5,892	607	2,448	642	3,423	3,076	2,107	360	610
1987 (prel.)	100,945	11,399	72,661	25,495	47,166	10,268	6,226	660	2,673	709	3,571	3,047	1,997	378	671
1988 (est.)	104,055	11,964	74,752	25,990	48,762	10,726	6,436	701	2,863	726	3,630	2,983	1,898	396	689
1989 (est.)	105,131	11,717	75,741	26,015	49,726	11,041	6,553	731	3,019	739	3,694	2,939	1,827	409	703

[1] Total funds used by Federal Government from Federal sources.

[2] Expenditures in federally funded research and development centers (FFRDC) administered by industry or nonprofit institutions are included in the totals for the respective sector.

[3] FFRDCs administered by universities and colleges and by university consortia.

[4] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars. Current dollars will differ slightly from source document.

Note: Data based on annual reports by performers except for the nonprofit sector, for which data are estimated.

SOURCES: NSF, *National Patterns of R&D Resources: 1989*, NSF 89-308 (Washington, DC: NSF, 1989); and unpublished tabulations.

See figures 4-1 and 4-2, figure O-19 in Overview, and text table 4-1.

Appendix table 4-3. National expenditures for development, by performer and source: 1960-89

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of current dollars														
1960	9,306	971	8,104	5,169	2,935	34	18	3	11	2	141	56	36	10	10
1961	9,850	1,034	8,536	5,347	3,189	35	20	2	11	2	160	85	61	10	14
1962	10,005	1,145	8,527	5,281	3,246	40	23	2	13	2	179	114	85	11	18
1963	11,352	1,309	9,651	6,116	3,535	40	22	2	14	2	201	151	120	11	20
1964	12,437	1,621	10,363	6,515	3,848	40	22	2	14	2	236	177	148	11	18
1965	13,150	1,739	10,935	6,516	4,419	57	37	2	15	3	217	202	170	12	20
1966	14,431	1,838	12,081	7,120	4,961	84	59	2	18	5	196	232	195	14	23
1967	15,310	1,934	12,841	7,097	5,744	90	63	2	20	5	204	241	202	15	24
1968	16,178	1,952	13,663	7,337	6,326	96	68	3	17	8	212	255	213	16	26
1969	16,874	1,857	14,403	7,276	7,127	107	75	5	17	10	240	267	221	18	28
1970	16,865	2,175	14,038	6,572	7,466	112	84	5	13	10	252	288	240	18	30
1971	17,265	2,340	14,315	6,558	7,757	112	83	5	14	10	246	252	200	19	33
1972	18,664	2,605	15,445	6,935	8,510	84	55	3	19	7	288	242	188	19	35
1973	20,175	2,674	16,793	7,020	9,773	118	70	4	33	11	294	296	238	20	38
1974	21,331	2,641	17,900	7,032	10,868	133	71	6	42	14	297	360	297	21	42
1975	22,663	2,890	18,887	7,318	11,569	148	78	7	47	16	335	403	330	22	51
1976	24,905	2,890	21,066	8,176	12,890	164	87	9	52	16	371	414	330	23	61
1977	27,397	3,054	23,278	8,950	14,328	200	112	14	58	16	413	452	352	27	73
1978	30,736	3,590	25,969	9,509	16,460	236	122	15	78	21	444	497	380	30	87
1979	35,149	3,936	29,843	10,698	19,145	284	160	16	85	23	482	604	470	35	99
1980	40,287	3,966	34,730	11,839	22,891	342	209	16	90	27	584	665	520	40	105
1981	45,592	4,391	39,497	13,741	25,756	388	225	21	111	31	621	695	540	45	110
1982	50,643	4,947	43,940	15,153	28,787	423	235	25	127	36	588	745	575	50	120
1983	55,568	5,872	47,746	16,465	31,281	443	245	26	132	40	652	855	670	55	130
1984	63,128	6,808	53,967	18,509	35,458	488	270	32	144	42	815	1,050	850	65	135
1985	69,469	7,889	58,732	21,073	37,659	586	320	41	174	51	1,027	1,235	1,000	75	160
1986	74,101	8,375	62,452	23,574	38,878	715	380	55	222	58	1,189	1,370	1,100	90	180
1987 (prel.)	77,839	7,975	66,500	25,600	40,900	767	400	60	243	64	1,292	1,305	1,000	95	210
1988 (est.)	82,700	8,880	70,450	26,900	43,550	820	420	65	265	70	1,330	1,220	900	100	220
1989 (est.)	86,480	8,980	74,000	27,900	46,100	870	440	70	290	70	1,400	1,230	900	105	225

(continued)

Appendix table 4-3. (Continued)

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of constant 1982 dollars[4]														
1960	29,913	3,121	26,050	16,615	9,434	109	58	10	35	6	453	180	116	32	32
1961	31,330	3,289	27,150	17,007	10,143	111	64	6	35	6	509	270	194	32	45
1962	31,266	3,578	26,647	16,503	10,144	125	72	6	41	6	559	356	266	34	56
1963	34,843	4,018	29,622	18,772	10,850	123	68	6	43	6	617	463	368	34	61
1964	37,631	4,905	31,356	19,713	11,643	121	67	6	42	6	714	536	448	33	54
1965	38,963	5,153	32,400	19,307	13,093	169	110	6	44	9	643	599	504	36	59
1966	41,540	5,291	34,775	20,495	14,280	242	170	6	52	14	564	668	561	40	66
1967	42,611	5,383	35,739	19,752	15,987	250	175	6	56	14	568	671	562	42	67
1968	43,501	5,249	36,738	19,728	17,010	258	183	8	46	22	570	686	573	43	70
1969	43,046	4,737	36,742	18,561	18,181	273	191	13	43	26	612	681	564	46	71
1970	40,658	5,243	33,843	15,844	17,999	270	203	12	31	24	608	694	579	43	72
1971	39,544	5,360	32,787	15,021	17,767	257	190	11	32	23	563	577	458	44	76
1972	40,521	5,656	33,532	15,056	18,476	182	119	7	41	15	625	525	408	41	76
1973	41,727	5,531	34,732	14,519	20,213	244	145	8	68	23	608	612	492	41	79
1974	40,895	5,063	34,317	13,482	20,836	255	136	12	81	27	569	690	569	40	81
1975	39,400	5,024	32,836	12,723	20,113	257	136	12	82	28	582	701	574	38	89
1976	40,118	4,655	33,934	13,170	20,764	264	140	14	84	26	598	667	532	37	98
1977	40,873	4,556	34,728	13,352	21,376	298	167	21	87	24	616	674	525	40	109
1978	42,856	5,006	36,209	13,259	22,950	329	170	21	109	29	619	693	530	42	121
1979	45,121	5,053	38,309	13,733	24,576	365	205	21	109	30	619	775	603	45	127
1980	47,542	4,680	40,984	13,971	27,013	404	247	19	106	32	689	785	614	47	124
1981	48,913	4,711	42,374	14,742	27,632	416	241	23	119	33	666	746	579	48	118
1982	50,643	4,947	43,940	15,153	28,787	423	235	25	127	36	586	745	575	50	120
1983	53,313	5,634	45,808	15,797	30,012	425	235	25	127	38	626	820	643	53	125
1984	58,349	6,293	49,882	17,108	32,774	451	250	30	133	39	753	971	786	60	125
1985	62,287	7,073	52,660	18,894	33,766	525	287	37	156	46	921	1,107	897	67	143
1986	64,672	7,309	54,505	20,574	33,931	624	332	48	194	51	1,038	1,196	960	79	157
1987 (prel.)	65,831	6,745	56,242	21,651	34,591	649	338	51	206	54	1,093	1,104	846	80	178
1988 (est.)	67,937	7,295	57,874	22,098	35,776	674	345	53	218	58	1,093	1,002	739	82	181
1989 (est.)	68,429	7,106	58,554	22,076	36,477	688	348	55	229	55	1,108	973	712	83	178

[1] Total funds used by Federal Government from Federal sources.

[2] Expenditures in federally funded research and development centers (FFRDC) administered by industry or nonprofit institutions are included in the totals for the respective sector.

[3] FFRDCs administered by universities and colleges and by university consortia.

[4] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars. Current dollars will differ slightly from source document.

Note: Data based on annual reports by performers except for the nonprofit sector, for which data are estimated.

SOURCES: NSF, *National Patterns of R&D Resources: 1989*, NSF 89-308 (Washington, DC: NSF, 1989); and unpublished tabulations.

See figures 4-1 and 4-2 and O-4 in Overview.

Appendix table 4-4. National expenditures for applied research, by performer and source: 1960-89

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of current dollars														
1960	3,020	595	2,029	833	1,196	179	88	13	66	12	122	95	50	17	28
1961	3,065	634	1,977	812	1,165	192	98	13	69	12	135	127	75	17	35
1962	3,665	702	2,449	1,011	1,438	205	109	13	70	13	155	154	90	19	45
1963	3,742	715	2,457	1,007	1,450	227	128	14	72	13	170	173	105	19	49
1964	4,128	903	2,600	1,040	1,560	232	127	14	77	14	202	191	125	19	47
1965	4,339	990	2,658	1,038	1,620	279	157	13	88	21	204	208	135	21	52
1966	4,601	997	2,843	1,039	1,804	328	194	13	89	32	207	226	145	24	57
1967	4,780	1,027	2,915	1,066	1,849	374	222	15	102	35	219	245	160	25	60
1968	5,131	1,110	3,124	1,043	2,081	404	254	16	97	37	231	262	172	28	62
1969	5,316	1,114	3,287	1,015	2,272	407	246	16	105	40	210	298	200	32	66
1970	5,720	1,327	3,427	1,049	2,378	427	268	16	98	45	216	323	220	33	70
1971	5,739	1,302	3,415	974	2,441	474	292	19	115	48	210	338	230	34	74
1972	5,984	1,360	3,514	952	2,562	524	320	18	140	46	221	365	251	35	79
1973	6,597	1,480	3,825	993	2,832	713	461	23	172	57	226	353	234	36	83
1974	7,189	1,574	4,288	1,025	3,263	736	438	29	203	66	178	413	280	40	93
1975	7,812	1,730	4,570	1,130	3,440	851	516	34	224	77	213	448	300	43	105
1976	8,983	2,093	5,112	1,200	3,912	1,016	584	43	283	106	264	498	330	48	120
1977	9,651	2,044	5,636	1,325	4,311	1,067	607	46	303	111	371	533	345	53	135
1978	10,701	2,192	6,300	1,430	4,870	1,213	673	56	354	130	406	590	385	55	150
1979	12,230	2,392	7,225	1,555	5,670	1,465	863	64	404	134	438	710	480	60	170
1980	13,892	2,484	8,450	1,900	6,550	1,695	1,035	80	445	135	538	725	480	65	180
1981	16,683	2,732	10,699	2,340	8,359	1,868	1,085	100	533	150	604	780	515	75	190
1982	18,311	2,729	12,175	2,950	9,225	2,018	1,121	118	607	172	574	815	540	85	190
1983	20,129	3,020	13,505	3,617	9,888	2,116	1,170	127	631	188	613	875	580	95	200
1984	21,959	2,903	15,028	4,182	10,846	2,404	1,329	160	708	207	694	930	600	110	220
1985	24,355	3,133	16,915	5,275	11,640	2,552	1,396	178	757	221	790	965	610	120	235
1986	23,307	3,141	15,611	3,727	11,884	2,699	1,433	208	838	220	891	965	600	130	235
1987 (prel.)	24,778	3,392	16,400	3,900	12,500	3,014	1,572	236	953	253	947	1,025	625	140	260
1988 (est.)	26,060	3,450	17,300	4,000	13,300	3,280	1,680	260	1,070	270	970	1,060	625	155	280
1989 (est.)	27,300	3,500	18,200	4,200	14,000	3,530	1,760	285	1,200	285	1,000	1,070	600	170	300

(continued)

Appendix table 4-4. (Continued)

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of constant 1982 dollars[4]														
1960	9,707	1,913	6,522	2,678	3,844	575	283	42	212	39	392	305	161	55	90
1961	9,749	2,017	6,288	2,583	3,705	611	312	41	219	38	429	404	239	54	111
1962	11,453	2,194	7,653	3,159	4,494	641	341	41	219	41	484	481	281	59	141
1963	11,486	2,195	7,541	3,091	4,451	697	393	43	221	40	522	531	322	58	150
1964	12,490	2,732	7,867	3,147	4,720	702	384	42	233	42	611	578	378	57	142
1965	12,856	2,933	7,876	3,076	4,800	827	465	39	261	62	604	616	400	62	154
1966	13,244	2,870	8,184	2,991	5,193	944	558	37	256	92	596	651	417	69	164
1967	13,304	2,858	8,113	2,967	5,146	1,041	618	42	284	97	610	682	445	70	167
1968	13,797	2,985	8,400	2,805	5,596	1,086	683	43	261	99	621	704	462	75	167
1969	13,561	2,842	8,385	2,589	5,796	1,038	628	41	268	102	536	760	510	82	168
1970	13,790	3,199	8,262	2,529	5,733	1,029	646	39	236	108	521	779	530	80	169
1971	13,145	2,982	7,822	2,231	5,591	1,086	669	44	263	110	481	774	527	78	169
1972	12,992	2,953	7,629	2,067	5,562	1,138	695	39	304	100	480	792	545	76	172
1973	13,644	3,061	7,911	2,054	5,857	1,475	953	48	356	118	467	730	484	74	172
1974	13,783	3,018	8,221	1,965	6,256	1,411	840	56	389	127	341	792	537	77	178
1975	13,581	3,008	7,945	1,965	5,981	1,479	897	59	389	134	370	779	522	75	183
1976	14,470	3,371	8,235	1,933	6,302	1,637	941	69	456	171	425	802	532	77	193
1977	14,398	3,049	8,408	1,977	6,431	1,592	906	69	452	166	553	795	515	79	201
1978	14,921	3,056	8,784	1,994	6,790	1,691	938	78	494	181	566	823	537	77	209
1979	15,700	3,071	9,275	1,996	7,279	1,881	1,108	82	519	172	562	911	616	77	218
1980	16,394	2,931	9,972	2,242	7,730	2,000	1,221	94	525	159	635	856	566	77	212
1981	17,898	2,931	11,478	2,510	8,968	2,004	1,164	107	572	161	648	837	553	80	204
1982	18,311	2,729	12,175	2,950	9,225	2,018	1,121	118	607	172	574	815	540	85	190
1983	19,312	2,897	12,957	3,470	9,487	2,030	1,123	122	605	180	588	839	556	91	192
1984	20,297	2,683	13,890	3,865	10,025	2,222	1,228	148	654	191	641	860	555	102	203
1985	21,837	2,809	15,166	4,730	10,437	2,288	1,252	160	679	198	708	865	547	108	211
1986	20,341	2,741	13,625	3,253	10,372	2,356	1,251	182	731	192	778	842	524	113	205
1987 (prel.)	20,956	2,869	13,870	3,298	10,572	2,549	1,329	200	806	214	801	867	529	118	220
1988 (est.)	21,408	2,834	14,212	3,286	10,926	2,694	1,380	214	879	222	797	871	513	127	230
1989 (est.)	21,602	2,769	14,401	3,323	11,078	2,793	1,393	226	950	226	791	847	475	135	237

[1] Total funds used by Federal Government from Federal sources.

[2] Expenditures in federally funded research and development centers (FFRDC) administered by industry or nonprofit institutions are included in the totals for the respective sector.

[3] FFRDCs administered by universities and colleges and by university consortia.

[4] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars. Current dollars will differ slightly from source document.

Note: Data based on annual reports by performers except for the nonprofit sector, for which data are estimated.

SOURCES: NSF, *National Patterns of R&D Resources: 1989*, NSF 89-308 (Washington, DC: NSF, 1989); and unpublished tabulations.

See figures 4-1 and 4-2 and O-4 in Overview.

Appendix table 4-5. National expenditures for basic research, by performer and source: 1960-89

			Industry²			Universities and colleges						Nonprofit institutions²			
	Total	Federal¹	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs³	Total	Federal	Industry	Nonprofits
	Millions of current dollars														
1960	1,197	160	376	79	297	433	299	24	72	38	97	131	80	21	30
1961	1,401	206	395	81	314	536	382	25	85	44	115	149	90	22	37
1962	1,724	251	488	143	345	659	481	25	102	51	136	190	120	24	46
1963	1,965	255	522	147	375	814	610	25	121	58	159	215	140	25	50
1964	2,289	314	549	165	384	1,003	768	24	144	67	191	232	160	25	47
1965	2,555	364	592	186	406	1,138	879	26	164	69	208	253	172	29	52
1966	2,814	385	624	173	451	1,303	1,008	27	197	71	227	275	185	32	58
1967	3,056	435	629	202	427	1,457	1,124	31	223	79	250	285	190	34	61
1968	3,296	432	642	180	462	1,649	1,251	36	276	86	276	297	197	37	63
1969	3,441	532	618	160	458	1,711	1,279	39	298	95	275	305	195	43	67
1970	3,549	577	602	158	444	1,796	1,296	40	350	110	269	305	189	44	72
1971	3,672	586	590	134	456	1,914	1,349	46	400	119	260	322	200	45	77
1972	3,829	625	593	130	463	2,022	1,420	53	415	134	244	345	214	47	84
1973	3,946	608	631	132	499	2,053	1,454	57	408	134	297	357	218	49	90
1974	4,344	696	699	163	536	2,154	1,523	61	432	138	390	405	245	54	106
1975	4,738	734	730	157	573	2,410	1,694	72	478	166	439	425	245	60	120
1976	5,130	786	819	185	634	2,549	1,841	71	475	162	512	464	265	64	135
1977	5,735	914	911	210	701	2,800	2,007	79	527	187	600	510	290	70	150
1978	6,692	1,029	1,035	250	785	3,176	2,264	99	605	208	867	585	335	80	170
1979	7,554	1,089	1,158	265	893	3,612	2,572	114	709	217	1,015	680	400	85	195
1980	8,415	1,182	1,325	290	1,035	4,024	2,852	142	791	239	1,124	760	450	95	215
1981	9,591	1,302	1,614	301	1,313	4,589	3,251	172	911	255	1,261	825	495	105	225
1982	10,410	1,465	1,880	380	1,500	4,883	3,403	196	1,001	283	1,317	865	535	115	215
1983	11,583	1,690	2,152	460	1,692	5,324	3,565	235	1,173	351	1,472	945	600	125	220
1984	12,706	1,861	2,475	471	2,004	5,731	3,826	282	1,255	368	1,609	1,030	650	150	230
1985	13,933	1,923	2,622	482	2,140	6,556	4,348	340	1,446	422	1,712	1,120	690	165	265
1986	15,089	2,019	2,568	482	2,086	7,512	4,900	429	1,729	454	1,820	1,170	700	190	280
1987 (prel.)	16,165	2,046	2,600	500	2,100	8,301	5,354	481	1,949	517	1,963	1,255	725	210	320
1988 (est.)	17,355	2,170	2,850	600	2,250	8,900	5,700	525	2,135	540	2,100	1,335	775	225	335
1989 (est.)	18,570	2,270	3,150	650	2,500	9,500	6,050	565	2,310	575	2,250	1,400	800	240	360

(continued)

Appendix table 4-5. (Continued)

			Industry[2]			Universities and colleges						Nonprofit institutions[2]			
	Total	Federal[1]	Total	Federal	Industry	Total	Federal	Industry	Universities and colleges	Nonprofits	FFRDCs[3]	Total	Federal	Industry	Nonprofits
	Millions of constant 1982 dollars[4]														
1960	3,848	514	1,209	254	955	1,392	961	77	231	122	312	421	257	68	96
1961	4,456	655	1,256	258	999	1,705	1,215	80	270	140	366	474	286	70	118
1962	5,388	784	1,525	447	1,078	2,059	1,503	78	319	159	425	594	375	75	144
1963	6,031	783	1,602	451	1,151	2,498	1,872	77	371	178	488	660	430	77	153
1964	6,926	950	1,661	499	1,162	3,035	2,324	73	436	203	578	702	484	76	142
1965	7,570	1,079	1,754	551	1,203	3,372	2,604	77	486	204	616	750	510	86	154
1966	8,100	1,108	1,796	498	1,298	3,751	2,902	78	567	204	653	792	533	92	167
1967	8,505	1,211	1,751	562	1,188	4,055	3,128	86	621	220	696	793	529	95	170
1968	8,863	1,162	1,726	484	1,242	4,434	3,364	97	742	231	742	799	530	99	169
1969	8,778	1,357	1,577	408	1,168	4,365	3,263	99	760	242	702	778	497	110	171
1970	8,556	1,391	1,451	381	1,070	4,330	3,124	96	844	265	649	735	456	106	174
1971	8,410	1,342	1,351	307	1,044	4,384	3,090	105	916	273	596	738	458	103	176
1972	8,313	1,357	1,287	282	1,005	4,390	3,083	115	901	291	530	749	465	102	182
1973	8,161	1,257	1,305	273	1,032	4,246	3,007	118	844	277	614	738	451	101	186
1974	8,328	1,334	1,340	313	1,028	4,130	2,920	117	828	265	748	776	470	104	203
1975	8,237	1,276	1,269	273	996	4,190	2,945	125	831	289	763	739	426	104	209
1976	8,264	1,266	1,319	298	1,021	4,106	2,966	114	765	261	825	747	427	103	217
1977	8,556	1,364	1,359	313	1,046	4,177	2,994	118	786	279	895	761	433	104	224
1978	9,331	1,435	1,443	349	1,095	4,428	3,157	138	844	290	1,209	816	467	112	237
1979	9,697	1,398	1,487	340	1,146	4,637	3,302	146	910	279	1,303	873	513	109	250
1980	9,930	1,395	1,564	342	1,221	4,749	3,366	168	933	282	1,326	897	531	112	254
1981	10,290	1,397	1,732	323	1,409	4,923	3,488	185	977	274	1,352	885	531	113	241
1982	10,410	1,465	1,880	380	1,500	4,883	3,403	196	1,001	283	1,317	865	535	115	215
1983	11,113	1,621	2,065	441	1,623	5,108	3,420	225	1,125	337	1,412	907	576	120	211
1984	11,744	1,720	2,288	435	1,852	5,297	3,536	261	1,160	340	1,487	952	601	139	213
1985	12,493	1,724	2,351	432	1,919	5,878	3,899	305	1,297	378	1,535	1,004	619	148	238
1986	13,169	1,762	2,241	421	1,821	6,556	4,276	374	1,509	396	1,588	1,021	611	166	244
1987 (prel.)	13,671	1,730	2,199	423	1,776	7,020	4,528	407	1,648	437	1,660	1,061	613	178	271
1988 (est.)	14,257	1,783	2,341	493	1,848	7,311	4,682	431	1,754	444	1,725	1,097	637	185	275
1989 (est.)	14,694	1,796	2,492	514	1,978	7,517	4,787	447	1,828	455	1,780	1,108	633	190	285

[1] Total funds used by Federal Government from Federal sources.

[2] Expenditures in federally funded research and development centers (FFRDC) administered by industry or nonprofit institutions are included in the totals for the respective sector.

[3] FFRDCs administered by universities and colleges and by university consortia.

[4] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars. Current dollars will differ slightly from source document.

Note: Data based on annual reports by performers except for the nonprofit sector, for which data are estimated.

SOURCES: NSF, *National Patterns of R&D Resources: 1989*, NSF 89-308 (Washington, DC: NSF, 1989); and unpublished tabulations.

See figures 4-1 and 4-2 and O-4 in Overview.

Appendix table 4-6. Federal obligations for R&D, by agency and character of work: 1980-89

Department/agency	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Research & development	Millions of dollars									
Total, all agencies	29,830	33,104	36,433	38,712	42,225	48,360	51,412	55,255	58,512	60,323
Department of Agriculture	688	774	797	848	866	943	929	948	1,020	987
Department of Commerce	343	328	336	335	358	399	399	402	411	308
Department of Defense	13,981	16,509	20,623	22,993	25,373	29,792	32,938	35,232	36,543	37,505
Department of Education	139	105	128	112	116	125	121	133	159	157
Department of Energy	4,754	4,918	4,708	4,537	4,674	4,966	4,688	4,757	5,101	5,182
Department of Health & Human Services	3,780	3,927	3,941	4,353	4,831	5,451	5,658	6,609	7,112	7,043
National Institutes of Health	3,182	3,333	3,433	3,789	4,257	4,828	5,005	5,853	6,321	6,233
Department of Housing & Urban Development	56	48	29	32	18	19	15	16	19	19
Department of the Interior	411	427	381	383	411	392	385	404	420	376
Department of Labor	138	62	25	20	16	13	10	22	27	24
Department of Transportation	361	416	310	348	448	429	386	324	323	316
Environmental Protection Agency	345	326	335	241	261	320	317	348	350	374
National Aeronautics & Space Administration	3,234	3,593	3,078	2,662	2,822	3,327	3,420	3,787	4,779	5,416
National Science Foundation	882	962	975	1,062	1,203	1,346	1,353	1,471	1,523	1,827
All other departments/agencies	718	710	766	789	828	839	793	804	724	790
Basic research										
Total, all agencies	4,674	5,041	5,482	6,260	7,067	7,819	8,153	8,944	9,623	10,300
Department of Agriculture	276	314	331	362	393	445	433	446	472	471
Department of Commerce	16	16	17	19	21	23	27	26	28	27
Department of Defense	540	604	687	786	848	861	924	908	885	947
Department of Education	18	21	14	14	12	15	5	3	4	5
Department of Energy	523	586	642	768	830	943	960	1,069	1,194	1,267
Department of Health & Human Services	1,763	1,900	2,145	2,475	2,815	3,233	3,339	3,830	4,115	4,240
National Institutes of Health	1,642	1,767	2,021	2,313	2,625	3,018	3,119	3,577	3,853	3,964
Department of the Interior	72	81	77	103	126	138	133	135	135	122
Department of Labor	4	4	7	5	5	3	1	1	1	1
Department of Transportation	0	1	1	1	4	1	1	0	0	0
Environmental Protection Agency	14	11	33	22	30	39	39	31	32	31
National Aeronautics & Space Administration	559	531	536	617	755	751	917	1,014	1,229	1,374
National Science Foundation	815	897	916	999	1,132	1,262	1,275	1,371	1,418	1,708
All other departments/agencies	76	76	78	89	98	105	102	111	112	109
Applied research										
Total, all agencies	6,923	7,172	7,541	7,993	7,911	8,315	8,349	8,999	9,241	9,413
Department of Agriculture	382	427	436	456	442	466	464	473	517	486
Department of Commerce	239	233	259	266	276	301	313	313	329	251
Department of Defense	1,721	1,997	2,266	2,437	2,201	2,307	2,303	2,440	2,320	2,407
Department of Education	70	33	56	62	69	77	91	104	108	114
Department of Energy	754	827	1,054	1,193	1,195	1,198	1,081	1,029	1,029	959
Department of Health & Human Services	1,570	1,592	1,461	1,545	1,652	1,796	1,851	2,195	2,362	2,273
National Institutes of Health	1,145	1,182	1,104	1,165	1,286	1,410	1,469	1,740	1,883	1,789
Department of Housing & Urban Development	20	17	10	11	6	7	5	6	7	7
Department of the Interior	283	289	275	255	254	231	235	247	260	232
Department of Labor	33	55	11	13	11	9	9	19	25	23
Department of Transportation	82	87	66	72	74	70	68	68	76	89
Environmental Protection Agency	232	208	211	152	142	176	179	246	243	261
National Aeronautics & Space Administration	1,051	876	871	928	955	1,033	1,152	1,256	1,413	1,700
National Science Foundation	58	59	57	63	71	84	78	99	105	119
All other departments/agencies	429	472	508	541	564	560	520	503	448	495

(continued)

Appendix table 4-6. (Continued)

Department/agency	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Development										
Total, all agencies	18,233	20,891	23,410	24,458	27,246	32,226	34,910	37,313	39,648	40,611
Department of Agriculture	30	33	31	30	31	32	32	29	31	31
Department of Commerce	88	79	60	50	62	75	60	64	55	30
Department of Defense	11,719	13,908	17,670	19,770	22,324	26,623	29,711	31,884	33,338	34,151
Department of Education	52	51	58	36	35	33	26	26	47	38
Department of Energy	3,476	3,505	3,012	2,576	2,649	2,825	2,648	2,659	2,878	2,956
Department of Health & Human Services	447	435	335	332	365	423	468	584	636	531
National Institutes of Health	394	385	309	311	347	400	418	536	585	480
Department of Housing & Urban Development	36	31	19	21	12	12	10	11	12	12
Department of the Interior	57	57	30	25	31	22	17	22	25	23
Department of Labor	102	4	8	2	0	1	1	1	1	1
Department of Transportation	279	327	243	275	371	358	317	256	248	227
Environmental Protection Agency	100	107	92	66	89	106	100	71	76	83
National Aeronautics & Space Administration	1,624	2,186	1,671	1,117	1,113	1,544	1,351	1,518	2,138	2,342
National Science Foundation	8	6	2	0	0	0	0	0	0	0
All other departments/agencies	214	162	180	159	166	173	170	188	165	186
Research & development	Millions of constant 1982 dollars									
Total, all agencies	35,202	35,515	36,433	37,140	39,028	43,360	44,870	46,732	48,067	47,732
Department of Agriculture	811	830	797	813	801	846	810	802	838	781
Department of Commerce	404	352	336	321	331	358	348	340	337	244
Department of Defense	16,499	17,711	20,623	22,060	23,452	26,712	28,747	29,797	30,020	29,676
Department of Education	165	113	128	107	107	112	106	112	131	124
Department of Energy	5,610	5,276	4,708	4,353	4,320	4,453	4,092	4,023	4,190	4,100
Department of Health & Human Services	4,461	4,213	3,941	4,176	4,465	4,887	4,938	5,589	5,843	5,573
National Institutes of Health	3,755	3,576	3,433	3,635	3,935	4,329	4,368	4,950	5,193	4,932
Department of Housing & Urban Development	66	52	29	31	17	17	13	14	16	15
Department of the Interior	485	458	381	367	380	351	336	342	345	297
Department of Labor	163	67	25	19	15	12	9	18	22	19
Department of Transportation	426	446	310	334	414	385	336	274	266	250
Environmental Protection Agency	407	349	335	231	241	287	277	294	288	296
National Aeronautics & Space Administration	3,816	3,855	3,078	2,554	2,608	2,983	2,985	3,203	3,926	4,286
National Science Foundation	1,041	1,032	975	1,019	1,112	1,206	1,181	1,244	1,251	1,445
All other departments/agencies	848	762	766	757	765	752	692	680	595	625
Basic research										
Total, all agencies	5,516	5,409	5,482	6,006	6,532	7,010	7,116	7,564	7,905	8,150
Department of Agriculture	325	337	331	347	363	399	378	377	388	372
Department of Commerce	19	17	17	18	19	21	23	22	23	21
Department of Defense	638	648	687	754	784	772	806	768	727	749
Department of Education	21	22	14	14	11	13	4	3	4	4
Department of Energy	617	629	642	737	768	845	838	904	981	1,003
Department of Health & Human Services	2,080	2,039	2,145	2,375	2,601	2,898	2,914	3,239	3,380	3,355
National Institutes of Health	1,938	1,896	2,021	2,219	2,426	2,706	2,722	3,025	3,165	3,137
Department of the Interior	84	87	77	99	116	124	116	114	110	96
Department of Labor	5	4	7	5	5	3	1	1	0	0
Department of Transportation	0	1	1	1	3	1	1	0	0	0
Environmental Protection Agency	16	11	33	21	27	35	34	26	26	24
National Aeronautics & Space Administration	660	570	536	592	697	673	800	857	1,009	1,087
National Science Foundation	962	962	916	959	1,047	1,131	1,113	1,160	1,165	1,351
All other departments/agencies	89	81	78	85	91	94	89	94	92	86

(continued)

Appendix table 4-6. (Continued)

Department/agency	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Applied research										
Total, all agencies	8,170	7,694	7,541	7,669	7,313	7,455	7,287	7,610	7,592	7,448
Department of Agriculture	451	458	436	437	409	417	405	400	425	384
Department of Commerce	281	250	259	255	255	270	273	265	270	199
Department of Defense	2,031	2,142	2,266	2,338	2,034	2,068	2,010	2,064	1,906	1,904
Department of Education	83	36	56	59	63	69	80	88	89	90
Department of Energy	890	888	1,054	1,145	1,104	1,075	943	871	845	759
Department of Health & Human Services	1,853	1,708	1,461	1,483	1,526	1,610	1,615	1,856	1,941	1,798
National Institutes of Health	1,351	1,268	1,104	1,118	1,188	1,264	1,282	1,471	1,547	1,415
Department of Housing & Urban Development	23	18	10	11	6	6	5	5	6	5
Department of the Interior	334	310	275	244	235	207	205	209	214	183
Department of Labor	38	58	11	12	10	8	8	16	21	18
Department of Transportation	97	94	66	69	69	63	59	58	62	70
Environmental Protection Agency	273	223	211	146	132	158	156	208	199	206
National Aeronautics & Space Administration	1,240	940	871	890	882	926	1,006	1,062	1,161	1,345
National Science Foundation	69	63	57	60	65	75	68	84	86	94
All other departments/agencies	507	506	508	519	521	502	454	426	368	392
Development										
Total, all agencies	21,517	22,413	23,410	23,465	25,184	28,895	30,468	31,557	32,571	32,134
Department of Agriculture	36	35	31	29	29	29	28	25	25	25
Department of Commerce	104	84	60	48	57	67	52	54	45	24
Department of Defense	13,830	14,921	17,670	18,968	20,634	23,871	25,930	26,965	27,387	27,023
Department of Education	61	55	58	34	32	30	22	22	38	30
Department of Energy	4,102	3,760	3,012	2,471	2,448	2,533	2,311	2,249	2,364	2,339
Department of Health & Human Services	528	467	335	318	337	379	408	494	522	420
National Institutes of Health	465	413	309	298	321	358	364	453	481	380
Department of Housing & Urban Development	43	34	19	20	11	11	9	9	10	10
Department of the Interior	67	61	30	24	28	20	15	18	21	18
Department of Labor	120	4	8	2	0	1	1	1	1	1
Department of Transportation	329	351	243	264	343	321	277	216	203	180
Environmental Protection Agency	118	115	92	63	82	95	87	60	62	66
National Aeronautics & Space Administration	1,917	2,345	1,671	1,071	1,028	1,384	1,179	1,284	1,756	1,853
National Science Foundation	10	7	2	0	0	0	0	0	0	0
All other departments/agencies	253	174	180	153	153	155	149	159	135	147

Note: Data for 1988 and 1989 are estimates.

SOURCE: NSF, Division of Science Resources Studies.

See figures 4-3 and 4-4.

Appendix table 4-7. Federal obligations for R&D, by character of work and performer: 1980-89

Performer	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of current dollars									
Total research and development	29,830	33,104	36,433	38,712	42,225	48,360	51,412	55,255	58,512	60,323
Federal intramural[1]	7,632	8,426	9,141	10,582	11,572	12,945	13,535	13,413	14,514	14,745
Industrial firms excluding FFRDCs	12,969	14,868	17,192	17,148	18,753	21,969	24,509	26,752	28,233	29,184
FFRDCs administered by industry	1,408	1,414	1,506	1,501	1,608	1,791	1,697	1,860	1,888	1,923
Universities & colleges excluding FFRDCs	4,263	4,466	4,606	4,966	5,565	6,358	6,579	7,354	7,771	8,167
FFRDCs administered by universities	1,533	1,791	1,977	2,266	2,325	2,535	2,440	3,210	3,371	3,638
Nonprofit institutions excluding FFRDCs	1,106	1,069	1,092	1,242	1,497	1,699	1,676	1,711	1,801	1,706
FFRDCs administered by nonprofit institutions	442	525	521	581	597	689	553	511	514	528
State & local governments	266	222	184	186	131	129	128	148	148	142
Foreign	211	323	214	240	176	245	296	298	272	290
Total basic research	4,674	5,041	5,482	6,260	7,067	7,819	8,153	8,944	9,623	10,300
Federal intramural[1]	1,183	1,302	1,466	1,690	1,861	1,923	2,019	2,046	2,173	2,269
Industrial firms excluding FFRDCs	325	293	271	306	394	408	545	467	583	659
FFRDCs administered by industry	70	73	87	83	91	123	118	120	135	142
Universities & colleges excluding FFRDCs	2,320	2,503	2,727	3,112	3,531	4,039	4,132	4,666	4,927	5,308
FFRDCs administered by universities	437	491	517	591	653	696	691	907	1,009	1,101
Nonprofit institutions excluding FFRDCs	280	313	356	410	474	556	572	658	713	734
FFRDCs administered by nonprofit institutions	8	9	9	8	8	12	13	13	14	15
State & local governments	24	27	25	32	28	31	31	38	40	41
Foreign	28	31	25	29	28	31	33	30	30	30
Total applied research	6,923	7,172	7,541	7,993	7,911	8,315	8,349	8,999	9,241	9,413
Federal intramural[1]	2,484	2,732	2,729	3,020	2,904	3,133	3,142	3,392	3,452	3,505
Industrial firms excluding FFRDCs	1,752	1,665	1,886	1,847	1,792	1,751	1,835	1,982	1,975	2,151
FFRDCs administered by industry	241	278	400	440	405	363	365	314	314	316
Universities & colleges excluding FFRDCs	1,379	1,417	1,318	1,356	1,499	1,688	1,751	1,975	2,124	2,118
FFRDCs administered by universities	414	450	540	621	635	641	502	564	593	585
Nonprofit institutions excluding FFRDCs	399	392	388	427	449	489	490	550	576	528
FFRDCs administered by nonprofit institutions	64	59	95	77	79	85	76	77	71	73
State & local governments	127	103	101	105	60	59	60	53	53	49
Foreign	63	75	83	101	89	107	130	94	83	89
Total development	18,233	20,891	23,410	24,458	27,246	32,226	34,910	37,313	39,648	40,611
Federal intramural[1]	3,966	4,392	4,947	5,872	6,808	7,889	8,375	7,975	8,889	8,971
Industrial firms excluding FFRDCs	10,892	12,910	15,036	14,995	16,567	19,810	22,129	24,303	25,676	26,374
FFRDCs administered by industry	1,097	1,063	1,019	979	1,112	1,305	1,215	1,426	1,439	1,465
Universities & colleges excluding FFRDCs	564	546	560	499	535	631	696	713	720	741
FFRDCs administered by universities	682	850	920	1,054	1,037	1,198	1,247	1,739	1,770	1,952
Nonprofit institutions excluding FFRDCs	427	364	348	405	575	654	614	503	512	445
FFRDCs administered by nonprofit institutions	370	458	416	496	510	592	463	421	430	441
State & local governments	115	93	58	49	43	40	37	58	55	52
Foreign	120	218	106	110	59	107	134	173	159	171

(continued)

Appendix table 4-7. (Continued)

Performer	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of constant 1982 dollars									
Total research and development	35,202	35,515	36,433	37,140	39,028	43,360	44,870	46,732	48,067	47,732
Federal intramural[1]	9,007	9,039	9,141	10,152	10,696	11,607	11,813	11,344	11,923	11,667
Industrial firms excluding FFRDCs	15,305	15,951	17,192	16,452	17,333	19,698	21,390	22,625	23,193	23,092
FFRDCs administered by industry	1,662	1,517	1,506	1,440	1,487	1,606	1,481	1,573	1,551	1,521
Universities & colleges excluding FFRDCs	5,031	4,791	4,606	4,765	5,144	5,700	5,742	6,219	6,384	6,462
FFRDCs administered by universities	1,809	1,921	1,977	2,174	2,149	2,273	2,129	2,714	2,769	2,878
Nonprofit institutions excluding FFRDCs	1,305	1,147	1,092	1,191	1,384	1,524	1,462	1,447	1,479	1,350
FFRDCs administered by nonprofit institutions	521	563	521	558	552	618	482	432	422	418
State & local governments	313	238	184	178	121	116	112	125	122	112
Foreign	249	347	214	230	162	219	259	252	223	230
Total basic research	5,516	5,409	5,482	6,006	6,532	7,010	7,116	7,564	7,905	8,150
Federal intramural[1]	1,395	1,397	1,466	1,621	1,720	1,725	1,762	1,731	1,785	1,795
Industrial firms excluding FFRDCs	384	314	271	293	364	366	475	395	479	521
FFRDCs administered by industry	83	79	87	80	84	110	103	101	111	113
Universities & colleges excluding FFRDCs	2,738	2,686	2,727	2,986	3,264	3,621	3,606	3,946	4,048	4,200
FFRDCs administered by universities	515	526	517	567	603	624	603	767	829	871
Nonprofit institutions excluding FFRDCs	330	336	356	393	438	498	499	556	585	580
FFRDCs administered by nonprofit institutions	9	9	9	8	8	11	11	11	11	12
State & local governments	28	28	25	31	26	27	27	32	33	32
Foreign	33	33	25	27	26	28	29	26	25	24
Total applied research	8,170	7,694	7,541	7,669	7,313	7,455	7,287	7,610	7,592	7,448
Federal intramural[1]	2,931	2,931	2,729	2,898	2,684	2,809	2,742	2,868	2,836	2,774
Industrial firms excluding FFRDCs	2,068	1,787	1,886	1,772	1,656	1,570	1,601	1,676	1,622	1,702
FFRDCs administered by industry	284	298	400	422	375	326	318	265	258	250
Universities & colleges excluding FFRDCs	1,627	1,520	1,318	1,301	1,385	1,513	1,529	1,670	1,745	1,676
FFRDCs administered by universities	489	483	540	595	587	574	438	477	487	463
Nonprofit institutions excluding FFRDCs	471	421	388	410	415	439	427	465	474	417
FFRDCs administered by nonprofit institutions	76	63	95	74	73	76	66	65	58	57
State & local governments	150	110	101	100	55	53	52	45	44	39
Foreign	74	80	83	97	82	96	113	80	68	70
Total development	21,517	22,413	23,410	23,465	25,184	28,895	30,468	31,557	32,571	32,134
Federal intramural[1]	4,680	4,711	4,947	5,633	6,292	7,074	7,309	6,745	7,302	7,099
Industrial firms excluding FFRDCs	12,853	13,850	15,036	14,387	15,313	17,762	19,313	20,554	21,092	20,869
FFRDCs administered by industry	1,295	1,140	1,019	939	1,028	1,170	1,060	1,206	1,182	1,159
Universities & colleges excluding FFRDCs	666	585	560	478	495	566	607	603	591	586
FFRDCs administered by universities	805	912	920	1,011	959	1,074	1,088	1,470	1,454	1,544
Nonprofit institutions excluding FFRDCs	504	390	348	388	531	586	536	426	420	352
FFRDCs administered by nonprofit institutions	437	491	416	476	471	531	404	356	353	349
State & local governments	135	100	58	47	40	36	33	49	45	41
Foreign	142	233	106	105	55	96	117	147	130	135

FFRDC = Federally funded research and development center.

[1] Federal intramural activities cover costs associated with the administration of intramural and extramural programs by Federal personnel as well as actual intramural performance.

SOURCE: NSF, Division of Science Resources Studies.

Appendix table 4-8. Federal obligations to intramural performers for basic research, by agency: 1980-89

	All agencies	DOE	DOD	NIH	NASA	NSF	USDA	All other agencies
	Millions of dollars							
1980	1,182	6	199	320	225	68	180	184
1981	1,302	6	226	335	216	99	202	218
1982	1,466	7	246	405	251	112	219	226
1983	1,690	18	276	449	305	126	239	277
1984	1,861	11	303	479	345	130	274	319
1985	1,961	21	301	543	318	138	296	344
1986	2,018	25	308	579	363	126	293	323
1987	2,046	35	283	568	379	138	302	340
1988 (est.)	2,173	40	271	619	431	152	322	339
1989 (est.)	2,269	32	278	629	498	165	330	337

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

Science & Engineering Indicators—1989

Appendix table 4-9. Federal obligations for R&D, by selected agency, performer, and character of work: 1989

Performer	Total all agencies	DOD	DOE	NIH	NASA	NSF	All other agencies
	Millions of dollars						
Total research and development	60,323	37,505	5,182	6,233	5,416	1,827	4,161
Federal intramural	14,745	9,094	207	1,007	1,913	171	2,352
Industrial firms excluding FFRDCs	29,184	25,213	910	194	2,406	72	389
FFRDCs administered by industry	1,923	328	1,523	8	0	3	61
Universities & colleges excluding FFRDCs	8,167	1,129	395	4,028	351	1,384	880
FFRDCs administered by universities	3,638	877	2,011	30	577	97	47
Nonprofit institutions excluding FFRDCs	1,706	271	61	875	147	98	255
FFRDCs administered by nonprofit institutions	528	439	73	4	1	0	12
State & local governments	142	0	0	53	5	1	83
Foreign	290	153	2	35	17	1	83
Total basic research	10,299	947	1,267	3,964	1,374	1,708	1,039
Federal intramural	2,269	278	32	629	498	165	668
Industrial firms excluding FFRDCs	659	99	22	63	386	56	32
FFRDCs administered by industry	142	1	132	4	0	3	3
Universities & colleges excluding FFRDCs	5,308	538	270	2,660	245	1,297	298
FFRDCs administered by universities	1,101	9	774	19	202	96	0
Nonprofit institutions excluding FFRDCs	734	19	23	538	37	88	28
FFRDCs administered by nonprofit institutions	15	1	14	0	0	0	0
State & local governments	41	0	0	31	1	1	8
Foreign	30	3	0	19	5	1	3
Total applied research	9,412	2,407	959	1,789	1,700	119	2,439
Federal intramural	3,505	950	102	306	748	6	1,393
Industrial firms excluding FFRDCs	2,150	1,002	134	92	699	15	208
FFRDCs administered by industry	316	59	197	2	0	0	58
Universities & colleges excluding FFRDCs	2,118	261	114	1,091	47	87	517
FFRDCs administered by universities	585	68	335	6	151	0	24
Nonprofit institutions excluding FFRDCs	527	44	33	260	46	9	135
FFRDCs administered by nonprofit institutions	73	14	43	3	0	0	12
State & local governments	49	0	0	15	1	0	33
Foreign	89	8	1	14	7	0	60
Total development	40,611	34,151	2,956	480	2,342	0	682
Federal intramural	8,971	7,866	74	73	668	0	291
Industrial firms excluding FFRDCs	26,374	24,112	754	38	1,321	0	149
FFRDCs administered by industry	1,465	269	1,194	2	0	0	0
Universities & colleges excluding FFRDCs	741	330	11	277	59	0	64
FFRDCs administered by universities	1,952	800	902	4	224	0	22
Nonprofit institutions excluding FFRDCs	445	208	5	77	63	0	92
FFRDCs administered by nonprofit institutions	441	424	16	0	0	0	0
State & local governments	52	0	0	7	3	0	43
Foreign	171	143	0	2	5	0	21

FFRDC = Federally funded research and development center.

Note: Data are estimates.

SOURCE: NSF, Division of Science Resources Studies, unpublished tabulations.

See text table 4-3.

Science & Engineering Indicators—1989

Appendix table 4-10. Federal obligations for basic research in industry, by agency: 1967-89

	All agencies	DOE[1]	DOD	NIH	NASA	NSF	USDA	All other agencies
	Millions of current dollars							
1967	181	2	28	10	138	2	0	1
1968	195	2	21	8	163	1	0	1
1969	185	2	18	5	154	2	0	5
1970	185	1	30	6	146	1	0	1
1971	167	1	42	7	114	1	0	1
1972	151	1	37	10	97	2	0	4
1973	176	0	35	11	125	3	1	1
1974	124	1	38	16	64	3	1	3
1975	119	0	42	11	53	6	0	5
1976	131	0	41	14	66	6	0	3
1977	208	1	51	13	135	5	1	4
1978	248	2	57	14	153	12	1	8
1979	277	2	66	19	175	6	2	7
1980	325	4	88	18	195	11	3	8
1981	293	7	77	18	161	20	4	6
1982	271	6	100	13	119	20	0	12
1983	306	25	105	20	127	21	0	7
1984	394	22	91	28	215	24	0	14
1985	404	23	92	27	210	32	0	20
1986	545	19	94	34	314	58	0	27
1987	467	20	101	57	228	42	1	18
1988 (est.)	583	34	87	62	326	47	0	25
1989 (est.)	659	22	99	63	386	56	0	31
	Millions of constant 1982 dollars							
1967	503	5	79	27	384	4	1	3
1968	524	5	56	21	437	3	1	2
1969	471	4	45	13	393	4	0	12
1970	446	3	71	15	352	2	0	2
1971	382	2	97	15	262	3	0	2
1972	329	1	80	22	211	4	0	10
1973	364	0	73	22	259	5	2	2
1974	238	1	72	30	123	5	1	5
1975	206	0	73	20	93	11	1	9
1976	211	0	66	23	106	10	0	5
1977	311	1	76	19	201	7	1	5
1978	345	3	80	20	213	17	1	12
1979	356	2	85	25	224	8	3	9
1980	384	5	103	21	230	13	3	9
1981	314	8	82	20	172	21	4	7
1982	271	6	100	13	119	20	0	12
1983	293	24	100	19	122	20	0	7
1984	364	20	84	26	198	23	0	13
1985	362	21	83	24	188	29	0	18
1986	475	16	82	29	274	51	0	23
1987	395	17	85	48	193	36	1	15
1988 (est.)	479	28	71	51	268	39	0	21
1989 (est.)	521	17	78	50	306	45	0	25

[1] Atomic Energy Commission, 1967-73; Energy Research and Development Administration, 1974-76; Department of Energy, 1977-present.

SOURCES: NSF, *Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1955-87, and Fiscal Years 1986, 1987, and 1988* (Washington, DC: NSF); and unpublished tabulations.

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Appendix table 4-11. Federal obligations for basic research, by S/E field: 1980-89

S/E field	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of current dollars									
Total, all fields	4,674	5,041	5,482	6,260	7,067	7,819	8,153	8,944	9,623	10,300
Life sciences, total	2,054	2,224	2,526	2,891	3,288	3,787	3,859	4,364	4,674	4,860
Biological & agricultural, total	1,339	1,462	1,675	1,929	2,175	2,516	2,543	2,870	3,079	3,219
Biol (excl. environmental)	1,100	1,202	1,401	1,622	1,836	2,106	2,152	2,462	2,640	2,765
Environmental biology	86	83	83	93	121	126	126	141	145	158
Agricultural	154	177	190	214	218	284	266	268	294	296
Medical sciences, total	657	706	793	879	1,015	1,145	1,197	1,343	1,430	1,470
Life sciences, N.E.C.	58	55	58	84	98	126	119	151	165	171
Psychology, total	84	91	90	93	108	133	133	147	151	162
Physical sciences, total	1,221	1,325	1,394	1,587	1,728	1,815	1,914	2,096	2,285	2,548
Astronomy	279	274	271	355	380	401	453	505	582	656
Chemistry	257	298	312	362	403	425	433	445	456	486
Physics	668	735	791	855	921	960	1,003	1,072	1,175	1,308
Physical sciences, N.E.C.	16	17	20	15	24	30	25	74	72	99
Environmental sciences, total	522	533	520	580	657	700	749	781	863	946
Atmospheric science	179	174	163	173	192	209	240	244	271	302
Geological	198	194	178	178	198	250	266	266	293	332
Oceanography	131	143	155	196	220	219	224	250	272	284
Environmental sciences, N.E.C.	14	22	25	34	46	21	19	21	26	28
Mathematics & computer science, total	116	140	165	208	241	260	293	306	331	396
Mathematics	67	79	91	101	114	130	142	158	164	180
Computer science	46	52	67	90	105	116	131	129	143	182
Mathematics & computer science, N.E.C.	3	9	7	17	22	14	20	20	24	34
Social sciences, total	147	137	120	138	133	141	114	130	134	136
Anthropology	14	13	13	11	17	16	11	12	13	13
Economics	40	34	39	41	30	34	26	29	30	32
Political science	7	6	4	5	4	6	4	6	6	5
Sociology	25	23	19	33	34	32	30	34	36	35
Social sciences, N.E.C.	60	61	45	48	48	52	42	48	49	51
Engineering, total	465	526	611	690	845	884	969	990	1,058	1,115
Aeronautical	104	113	127	141	226	192	226	237	280	314
Astronautical	27	33	45	50	52	42	53	49	62	70
Chemical	26	31	35	50	56	74	73	78	88	69
Civil	22	23	32	32	42	44	45	46	83	55
Electrical	71	79	94	96	130	145	156	175	128	165
Mechanical	42	47	53	61	64	88	84	87	93	92
Metallurgy & materials	121	139	156	183	187	212	229	210	215	238
Engineering, N.E.C.	52	61	69	76	88	88	103	108	109	112

(continued)

Appendix table 4-11. (Continued)

S/E field	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of constant 1982 dollars									
Total, all fields	5,516	5,409	5,482	6,006	6,532	7,010	7,116	7,564	7,905	8,150
Life sciences, total	2,424	2,386	2,526	2,774	3,039	3,395	3,368	3,690	3,840	3,845
Biological & agricultural, total	1,581	1,569	1,675	1,851	2,010	2,255	2,219	2,428	2,530	2,547
Biol (excl. environmental)	1,298	1,289	1,401	1,556	1,697	1,889	1,878	2,082	2,169	2,188
Environmental biology	102	89	83	89	112	113	110	119	119	125
Agricultural	181	190	190	206	202	254	232	227	242	234
Medical sciences, total	775	758	793	843	938	1,027	1,044	1,136	1,175	1,163
Life sciences, N.E.C.	68	59	58	80	90	113	104	127	135	135
Psychology, total	99	98	90	89	100	119	116	124	124	128
Physical sciences, total	1,440	1,421	1,394	1,523	1,597	1,628	1,671	1,773	1,877	2,016
Astronomy	330	294	271	340	351	359	395	427	478	519
Chemistry	303	320	312	348	373	381	378	376	374	384
Physics	789	789	791	820	852	861	876	907	965	1,035
Physical sciences, N.E.C.	19	18	20	15	22	27	22	63	59	78
Environmental sciences, total	616	572	520	557	607	627	654	661	709	748
Atmospheric science	211	186	163	166	178	188	210	206	223	239
Geological	234	208	178	171	183	224	232	225	241	262
Oceanography	154	154	155	188	203	197	196	211	224	225
Environmental sciences, N.E.C.	17	23	25	32	43	19	16	18	21	22
Mathematics & computer science, total	137	151	165	200	223	233	256	259	272	313
Mathematics	79	85	91	97	105	117	124	134	135	143
Computer science	55	56	67	87	97	104	115	109	118	144
Mathematics & computer science, N.E.C.	4	10	7	16	21	12	17	16	19	27
Social sciences, total	174	147	120	132	123	126	99	110	110	108
Anthropology	17	14	13	11	16	14	10	10	10	11
Economics	47	37	39	39	27	31	23	25	25	25
Political science	9	7	4	4	4	5	4	5	5	4
Sociology	30	24	19	31	31	29	26	29	29	27
Social sciences, N.E.C.	71	65	45	46	44	47	37	41	41	41
Engineering, total	549	564	611	662	781	793	845	837	869	882
Aeronautical	123	122	127	135	208	172	198	201	230	249
Astronautical	32	36	45	48	48	37	46	41	51	55
Chemical	31	34	35	48	51	67	64	66	73	55
Civil	26	25	32	31	39	39	39	39	68	43
Electrical	83	84	94	92	121	130	136	148	105	130
Mechanical	50	51	53	58	59	79	73	74	76	73
Metallurgy & materials	143	149	156	175	173	190	199	177	176	188
Engineering, N.E.C.	61	65	69	73	81	79	90	91	90	89

N.E.C. = Not elsewhere classified.

SOURCE: NSF, Division of Science Resources Studies, *Federal Funds for Research and Development: Fiscal Years 1987, 1988, and 1989*, NSF 89-304 (Washington, DC: NSF, 1989).

Appendix table 4-12. Federal obligations for applied research, by S/E field: 1980-89

S/E field	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of current dollars									
Total, all fields	6,923	7,172	7,541	7,993	7,911	8,315	8,349	8,999	9,241	9,413
Life sciences, total	2,138	2,212	2,220	2,287	2,348	2,576	2,606	2,980	3,135	3,094
Biological & agricultural, total	1,168	1,249	1,137	1,136	1,150	1,240	1,318	1,488	1,576	1,557
Biol (excl. environmental)	731	795	678	684	727	779	842	1,041	1,120	1,083
Environmental biology	144	137	100	101	129	135	138	149	153	170
Agricultural	294	317	359	351	294	326	338	299	303	304
Medical sciences, total	880	904	980	1,049	1,098	1,223	1,164	1,324	1,395	1,351
Life sciences, N.E.C.	90	59	103	102	100	113	123	168	165	187
Psychology, total	115	118	129	148	159	194	201	222	227	235
Physical sciences, total	780	896	1,107	1,304	1,241	1,231	1,155	1,157	1,102	1,160
Astronomy	6	7	5	3	3	14	15	18	17	20
Chemistry	198	189	169	158	203	225	229	235	222	219
Physics	514	610	820	1,000	915	856	803	781	765	804
Physical sciences, N.E.C.	62	90	113	144	120	135	108	122	98	116
Environmental sciences, total	739	588	628	671	619	704	733	731	768	745
Atmospheric science	231	200	263	288	242	277	281	309	312	344
Geological	203	202	180	155	161	179	178	176	189	180
Oceanography	131	118	107	148	143	179	205	178	190	138
Environmental sciences, N.E.C.	173	68	79	80	73	69	68	68	78	84
Mathematics & computer science, total	125	139	185	211	200	315	322	334	351	391
Mathematics	24	39	37	33	37	53	42	46	48	50
Computer science	82	69	104	124	110	164	171	169	172	182
Mathematics & computer science, N.E.C.	18	31	44	55	53	97	109	119	132	158
Social sciences, total	377	361	266	298	304	319	302	351	353	359
Anthropology	3	2	2	2	2	2	2	3	3	3
Economics	153	173	118	125	118	125	105	120	128	120
Political science	5	5	3	7	7	9	8	6	7	7
Sociology	46	42	33	35	36	34	37	40	38	39
Social sciences, N.E.C.	170	140	110	130	141	149	150	183	178	190
Sciences, N.E.C.	286	314	231	247	262	242	261	307	281	291
Engineering, total	2,365	2,545	2,776	2,828	2,779	2,733	2,770	2,917	3,024	3,138
Aeronautical	604	596	615	680	635	547	549	573	615	724
Astronautical	275	271	246	271	344	383	474	576	607	726
Chemical	70	116	60	95	89	180	173	138	156	118
Civil	137	136	170	156	161	173	158	159	160	167
Electrical	447	478	519	519	500	482	518	611	564	568
Mechanical	166	157	148	206	126	179	153	146	145	145
Metallurgy & materials	115	118	153	150	154	227	217	152	247	178
Engineering, N.E.C.	552	673	866	751	770	563	529	562	530	511

(continued)

Appendix table 4-12. (Continued)

S/E field	1980	1981	1982	1983	1984	1985	1986	1987	1988 (est.)	1989 (est.)
	Millions of constant 1982 dollars									
Total, all fields	8,170	7,694	7,541	7,669	7,313	7,455	7,287	7,610	7,592	7,448
Life sciences, total	2,523	2,373	2,220	2,194	2,171	2,310	2,274	2,520	2,575	2,448
Biological & agricultural, total	1,378	1,340	1,137	1,090	1,063	1,112	1,151	1,259	1,294	1,232
Biol (excl. environmental)	862	853	678	656	672	699	735	880	920	857
Environmental biology	169	147	100	97	119	121	121	126	126	135
Agricultural	347	341	359	337	272	292	295	253	249	241
Medical sciences, total	1,038	970	980	1,006	1,014	1,097	1,016	1,120	1,146	1,069
Life sciences, N.E.C.	106	63	103	98	93	101	108	142	135	148
Psychology, total	135	126	129	142	147	174	175	188	186	186
Physical sciences, total	920	961	1,107	1,251	1,147	1,104	1,008	978	905	917
Astronomy	7	7	5	3	2	13	13	15	14	16
Chemistry	233	202	169	152	188	202	200	199	182	173
Physics	607	655	820	959	846	768	700	661	628	636
Physical sciences, N.E.C.	73	96	113	138	111	121	94	104	81	92
Environmental sciences, total	872	631	628	644	572	631	639	618	631	589
Atmospheric science	272	214	263	276	224	248	245	261	256	272
Geological	240	217	180	149	149	160	156	149	155	142
Oceanography	155	127	107	142	133	161	179	150	156	109
Environmental sciences, N.E.C.	205	73	79	77	67	62	59	58	64	66
Mathematics & computer science, total	147	149	185	203	184	282	281	283	289	309
Mathematics	28	41	37	31	34	48	37	39	39	39
Computer science	97	74	104	119	101	147	149	143	141	144
Mathematics & computer science, N.E.C.	21	33	44	52	49	87	95	101	108	125
Social sciences, total	444	387	266	285	281	286	264	296	290	284
Anthropology	3	2	2	2	2	2	2	2	2	2
Economics	180	185	118	120	109	112	92	101	105	95
Political science	6	5	3	6	6	8	7	5	6	6
Sociology	54	45	33	34	34	30	32	33	31	31
Social sciences, N.E.C.	201	150	110	125	131	134	131	154	146	150
Sciences, N.E.C.	337	336	231	237	242	217	228	260	231	230
Engineering, total	2,791	2,731	2,776	2,713	2,569	2,451	2,418	2,467	2,484	2,483
Aeronautical	713	640	615	652	587	490	479	485	506	573
Astronautical	325	291	246	260	318	344	414	487	499	575
Chemical	83	125	60	91	82	161	151	117	128	94
Civil	161	146	170	150	149	155	138	134	132	132
Electrical	527	513	519	498	462	432	452	517	463	450
Mechanical	196	169	148	197	117	160	134	124	119	115
Metallurgy & materials	135	126	153	144	142	204	189	129	203	141
Engineering, N.E.C.	651	722	866	721	712	505	461	475	435	405

N.E.C. = Not elsewhere classified.

SOURCE: NSF, Division of Science Resources Studies, *Federal Funds for Research and Development, Fiscal Years 1987, 1988, and 1989*, NSF 89-304 (Washington, DC: NSF, 1989).

Appendix table 4-13. Federal obligations for defense and nondefense R&D, by character of work: 1960-89

	Total			Basic research			Applied research			Development		
	Total	Defense	Nondefense	Total	Defense	Nondefense	Total	Defense	Nondefense	Total	Defense	Nondefense
	Billions of constant 1982 dollars[1]											
1967	46.0	22.4	23.6	5.1	0.8	4.3	7.8	3.6	4.1	33.1	18.0	15.1
1968	42.8	20.7	22.1	4.9	0.7	4.2	7.9	3.5	4.4	30.0	16.5	13.5
1969	39.9	19.6	20.3	5.0	0.7	4.3	6.9	2.9	4.0	28.1	16.0	12.0
1970	37.0	17.7	19.2	4.6	0.8	3.9	7.2	2.4	4.7	25.2	14.5	10.6
1971	35.6	17.2	18.4	4.5	0.7	3.8	7.2	2.3	4.9	23.9	14.2	9.7
1972	35.8	18.1	17.8	4.7	0.7	4.0	7.3	2.6	4.7	23.8	14.8	9.0
1973	34.7	17.4	17.4	4.6	0.6	4.0	6.9	2.3	4.6	23.2	14.4	8.8
1974	33.4	16.1	17.2	4.6	0.6	4.0	7.3	2.2	5.1	21.5	13.4	8.1
1975	33.1	15.7	17.4	4.5	0.5	4.0	7.2	2.0	5.2	21.4	13.2	8.2
1976	33.5	15.6	17.9	4.5	0.5	3.9	7.8	1.9	5.9	21.2	13.1	8.1
1977	35.0	16.4	18.6	4.9	0.6	4.3	7.8	2.0	5.8	22.3	13.8	8.5
1978	36.0	16.1	19.9	5.2	0.6	4.6	8.2	2.0	6.3	22.6	13.6	9.1
1979	36.1	16.1	20.1	5.4	0.6	4.8	8.1	2.0	6.2	22.6	13.5	9.1
1980	35.2	16.5	18.7	5.5	0.6	4.9	8.2	2.0	6.1	21.5	13.8	7.7
1981	35.5	17.7	17.8	5.4	0.6	4.8	7.7	2.1	5.6	22.4	14.9	7.5
1982	36.4	20.6	15.8	5.5	0.7	4.8	7.5	2.3	5.3	23.4	17.7	5.7
1983	37.1	22.1	15.1	6.0	0.8	5.3	7.7	2.3	5.3	23.5	19.0	4.5
1984	39.0	23.5	15.6	6.5	0.8	5.7	7.3	2.0	5.3	25.2	20.6	4.5
1985	43.4	26.7	16.6	7.0	0.8	6.2	7.5	2.1	5.4	28.9	23.9	5.0
1986	44.9	28.7	16.1	7.1	0.8	6.3	7.3	2.0	5.3	30.5	25.9	4.5
1987 (est.)	46.7	29.8	16.9	7.6	0.8	6.8	7.6	2.1	5.5	31.6	27.0	4.6
1988 (est.)	48.1	30.0	18.0	7.9	0.7	7.2	7.6	1.9	5.7	32.6	27.4	5.2
1989 (est.)	47.7	29.7	18.1	8.1	0.7	7.4	7.4	1.9	5.5	32.1	27.0	5.1

[1] See appendix table 4-1. GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: NSF, *Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1986, 1987, and 1988* (Washington, DC: NSF); and unpublished tabulations.

See text table 4-2 and figure O-5 in Overview.

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Appendix table 4-14. Reimbursed and unreimbursed costs incurred for independent research and development (IR&D): 1976-87

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
	Millions of current dollars											
Total IR&D costs incurred by industry	1,388	1,560	1,788	2,104	2,373	2,796	3,654	4,017	5,173	5,034	5,042	4,715
Accepted by Government IR&D program	1,061	1,199	1,365	1,517	1,728	2,039	2,821	2,961	3,897	3,498	3,537	3,438
By DOD	544	598	643	708	812	1,056	1,338	1,601	1,884	2,099	2,198	2,116
By NASA	41	46	49	54	57	66	67	78	86	88	77	67
Unreimbursed	476	555	673	755	859	917	1,416	1,282	1,927	1,311	1,262	1,255
Not accepted under IR&D program	327	361	423	587	645	757	833	1,056	1,276	1,536	1,505	1,277

SOURCES: Defense Contract Audit Agency, *Summary of Independent Research and Development and Bid and Proposal Cost, 1979-88* (Washington, DC: Defense Contract Audit Agency, ongoing series); and NASA, unpublished tabulations.

See figure 4-5.

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Appendix table 4-15. Independent research and development reimbursements: 1978-87

	DOD and NASA IR&D reimbursement	DOD and NASA R&D obligations		IR&D as a percentage of	
		Total	Total to industry[1]	DOD and NASA R&D total[2] (a)	DOD and NASA R&D performed by industry[2] (b)
	Millions of dollars			Percent	
1978	692	14,887	9,458	4.6	7.3
1979	763	16,085	10,079	4.7	7.6
1980	866	17,215	11,038	5.0	7.8
1981	1,122	20,102	13,027	5.6	8.6
1982	1,405	23,701	15,376	5.9	9.1
1983	1,679	25,654	15,700	6.5	10.7
1984	1,970	28,195	17,340	7.0	11.4
1985	2,188	33,119	20,645	6.6	10.6
1986	2,275	36,358	23,232	6.2	9.8
1987 (est.)	2,183	40,429	25,725	5.3	8.5

[1] Includes R&D performed by federally funded research and development centers administered by the industrial sector.

[2] Percentages calculated as follows: numerator in (a) is total DOD and NASA R&D including IR&D; numerator in (b) is total DOD and NASA IR&D reimbursements, and denominator is NASA and DOD R&D performed by industry, including IR&D.

SOURCES: Defense Contract Audit Agency, *Summary of Independent Research and Development and Bid and Proposal Cost*, 1979-88 (Washington, DC: Defense Contract Audit Agency, ongoing series); NASA, unpublished tabulations; and NSF, *Federal Funds for Research and Development: Fiscal Years 1987, 1988, and 1989*, NSF 89-304, Detailed Historical Tables (Washington, DC: NSF, 1989).

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Appendix table 4-16. Federal R&D funding by budget function: FYs 1981-90

Function	1981	1982	1983	1984	1985	1986	1987	1988	1989 (est.)	1990 (est.)
	Millions of dollars									
Total	33,735	36,115	38,768	44,214	49,887	53,249	57,069	59,106	61,823	67,833
National defense	18,413	22,070	24,936	29,287	33,698	36,926	39,152	40,099	40,574	44,296
Health	3,871	3,869	4,298	4,779	5,418	5,565	6,556	7,076	7,724	8,229
Space research and technology	3,111	2,584	2,134	2,300	2,725	2,894	3,398	3,683	4,589	6,146
General science	1,340	1,359	1,502	1,676	1,862	1,873	2,042	2,160	2,379	2,652
Energy	4	3,012	2,578	2,581	2,389	2,286	2,053	2,126	2,427	2,333
Transportation	869	791	876	1,040	1,030	917	908	896	1,019	1,129
Natural resources and environment	1,061	965	952	963	1,059	1,062	1,133	1,160	1,208	1,140
Agriculture	659	693	745	762	836	815	822	882	910	901
Education, training, employment and social services	298	228	189	200	220	248	267	285	343	347
Veterans benefits and services	143	139	157	218	193	183	215	195	212	199
International affairs	160	165	177	192	210	211	223	224	141	169
Commerce and housing credit	106	104	107	110	114	111	110	122	134	132
Community and regional development	104	63	44	46	50	88	99	108	77	79
Administration of justice	34	31	37	24	47	41	49	51	45	40
Income security	43	32	32	26	21	14	25	23	27	25
General government	22	10	6	8	17	14	17	17	15	17

Note: Data for 1981-87 are shown in actual budget authority. Data for 1989 and 1990 are estimates based on the FY 1990 budget.

SOURCE: NSF, *Federal R&D Funding by Budget Function, Fiscal Years 1988-90*, NSF 89-306 (Washington, DC: NSF, 1989).

See figure 4-6.

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Appendix table 4-17. Budget authority for basic research, by function: FYs 1981-90

Function	1981	1982	1983	1984	1985	1986	1987	1988	1989 (est.)	1990 (est.)
	Millions of dollars									
Total	5,107	5,305	6,247	7,072	7,810	8,193	9,021	9,530	10,319	11,192
National defense	610	696	788	845	856	960	900	905	968	939
Health	1,951	1,953	2,475	2,813	3,243	3,324	3,851	4,087	4,416	4,756
Space research and technology	445	434	501	646	498	737	843	944	1,101	1,243
General science	1,256	1,296	1,439	1,606	1,779	1,795	1,942	2,061	2,268	2,525
Energy	220	260	320	365	428	456	511	571	614	634
Natural resources and environment	131	139	156	192	206	204	206	210	244	262
Transportation	89	102	117	125	255	184	231	197	249	226
Agriculture	281	295	326	353	406	390	397	428	438	457
International affairs	12	10	10	3	4	5	3	3	2	1
Education, training, employment and social services	66	78	70	77	86	83	78	83	86	94
Veterans benefits and services	15	13	14	15	15	15	17	17	19	15
Commerce and housing credit	17	17	19	20	23	26	26	28	28	28
Administration of justice	5	4	4	5	4	5	8	8	10	6
Community and regional development	5	7	6	5	6	6	4	7	5	4
Income security	3	0	0	0	0	0	0	0	0	0
General government	3	2	3	3	4	5	4	5	3	3

Note: Data for 1978-87 are shown in actual budget authority. Data for 1989 and 1990 are estimates based on the FY 1990 budget.

SOURCE: NSF, *Federal R&D Funding by Budget Function, Fiscal Years 1988-90*, NSF 89-306 (Washington, DC: NSF, 1989).

See figure 4-6.

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Appendix table 4-18. Industrial expenditures for R&D, by selected SIC code, character of work, and source of funds: 1986

Industry	SIC code	Total basic	Federal basic	Company basic	Total applied	Federal applied	Company applied	Total development	Federal development	Company development
		Millions of dollars								
Total, all industries		2,568	482	2,086	15,611	3,727	11,884	62,452	23,574	38,878
Chemicals and allied products	28	649	7	642	3,452	137	3,315	4,920	104	4,816
Industrial chemicals	281-82,286	303	7	296	1,715	136	1,579	2,041	104	1,937
Drugs and medicines	283	286	0	286	NA	NA	NA	NA	0	NA
Other chemicals	284-85,287-89	60	0	60	NA	NA	NA	NA	0	NA
Petroleum refining	29	NA	NA	NA	NA	NA	NA	987	3	984
Machinery	35	171	NA	NA	1,475	NA	NA	9,050	994	8,056
Office, computing, and accounting	357	NA	NA	NA	1,090	NA	NA	NA	NA	6,114
Other machinery, except electrical	351-56,358-59	NA	NA	NA	385	17	368	NA	NA	1,942
Electrical equipment	36	542	105	437	2,533	579	1,954	14,955	6,885	8,070
Communication equipment	366	304	55	249	1,275	422	853	7,385	3,332	4,053
Electronic components	367	197	NA	NA	521	NA	NA	2,402	530	1,872
Transportation equipment	37	283	156	127	3,467	1,816	1,651	22,621	12,868	9,753
Aircraft and missiles	372,376	237	154	83	2,719	1,668	1,051	13,284	10,277	3,007

SIC = Standard Industrial Classification.

NA = Not available (due to privacy/disclosure restrictions).

SOURCE: NSF, Division of Science Resources Studies, unpublished estimates.

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Appendix table 4-19. R&D expenditures, and R&D expenditures as a percentage of GNP: 1961-87

	R&D expenditures[1]					R&D expenditures as a percentage of GNP				
	France[2]	West Germany	Japan	United Kingdom	United States	France[2]	West Germany	Japan	United Kingdom	United States
	Billions of constant 1982 dollars					Percent				
1961 . . .	3.2	NA	3.9	8.1	45.8	1.4	NA	1.4	2.5	2.7
1962 . . .	3.6	4.2	4.4	NA	48.2	1.5	1.2	1.5	NA	2.7
1963 . . .	4.0	4.9	4.9	NA	52.6	1.6	1.4	1.5	NA	2.8
1964 . . .	5.0	5.8	5.5	8.4	57.2	1.8	1.6	1.5	2.3	2.9
1965 . . .	5.8	6.7	6.1	NA	59.4	2.0	1.7	1.6	NA	2.8
1966 . . .	6.3	7.3	6.6	8.8	62.6	2.1	1.8	1.5	2.3	2.8
1967 . . .	6.8	7.9	7.6	8.9	64.4	2.2	2.0	1.6	2.3	2.8
1968 . . .	7.0	8.4	9.0	9.1	65.5	2.1	2.0	1.7	2.2	2.8
1969 . . .	7.1	8.3	10.5	9.4	64.7	2.0	1.8	1.7	2.3	2.7
1970 . . .	7.1	9.9	12.4	NA	62.4	1.9	2.1	1.9	NA	2.6
1971 . . .	7.4	10.9	13.3	NA	60.4	1.9	2.2	1.9	NA	2.4
1972 . . .	7.7	11.4	14.7	9.3	61.4	1.9	2.2	1.9	2.1	2.3
1973 . . .	7.7	11.3	16.1	NA	62.4	1.8	2.1	2.0	NA	2.3
1974 . . .	8.1	11.5	16.4	NA	61.5	1.8	2.1	2.0	NA	2.2
1975 . . .	8.1	11.9	16.7	10.1	59.9	1.8	2.2	2.0	2.1	2.2
1976 . . .	8.4	12.1	17.3	NA	62.1	1.8	2.1	2.0	NA	2.2
1977 . . .	8.6	12.4	18.0	NA	63.7	1.8	2.1	2.0	NA	2.1
1978 . . .	8.9	13.3	19.1	11.1	66.8	1.8	2.2	2.0	2.2	2.1
1979 . . .	9.4	15.0	21.0	NA	70.1	1.8	2.4	2.1	NA	2.2
1980 . . .	9.8	15.3	23.1	NA	73.2	1.8	2.4	2.2	NA	2.3
1981 . . .	10.8	15.9	25.5	12.2	76.6	2.0	2.5	2.3	2.4	2.4
1982 . . .	11.5	16.3	27.4	NA	79.4	2.1	2.6	2.4	NA	2.5
1983 . . .	11.9	16.4	29.9	11.9	84.0	2.1	2.6	2.6	2.2	2.6
1984 . . .	12.6	16.9	32.4	NA	90.7	2.2	2.6	2.6	NA	2.6
1985 . . .	13.1	18.5	36.1	12.9	97.0	2.3	2.8	2.8	2.3	2.7
1986 . . .	13.6	18.6	36.6	13.8	98.6	2.3	2.7	2.8	2.4	2.7
1987 . . .	13.7	19.4	39.1	NA	100.8	2.3	2.8	2.9	NA	2.6

NA = Not available.

[1] Conversions of foreign currencies to U.S. dollars are calculated with OECD purchasing power parity exchange rates. Constant 1982 dollars are based on U.S. Department of Commerce GNP implicit price deflators.

[2] French data are based on Gross Domestic Product (GDP); consequently, percentages may be slightly overstated compared to GNP.

SOURCES: NSF; Organisation for Economic Co-operation and Development (OECD); International Monetary Fund; and national sources.

See figures O-1 and O-2 in Overview.

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Appendix table 4-20. Estimated nondefense R&D expenditures, and R&D expenditures as a percentage of GNP: 1971-87

	France	West Germany	Japan	United Kingdom	United States	France[1]	West Germany	Japan	United Kingdom	United States
	Billions of constant 1982 dollars[2]					As a percentage of GNP				
1971	5.7	10.1	13.2	NA	42.1	1.5	2.0	1.9	NA	1.7
1972	6.1	10.7	14.6	6.9	42.3	1.5	2.1	1.9	1.5	1.6
1973	6.0	10.5	16.0	NA	44.3	1.4	1.9	2.0	NA	1.6
1974	6.5	10.7	16.3	NA	44.8	1.4	2.0	2.0	NA	1.6
1975	6.6	11.2	16.6	7.2	43.6	1.5	2.1	2.0	1.5	1.6
1976	6.8	11.3	17.2	NA	45.6	1.4	2.0	2.0	NA	1.6
1977	7.0	11.6	17.9	NA	46.0	1.4	2.0	2.0	NA	1.6
1978	7.1	12.5	18.9	8.0	48.9	1.4	2.1	2.0	1.6	1.6
1979	7.4	14.2	20.8	NA	52.5	1.4	2.3	2.1	NA	1.6
1980	7.6	14.5	23.0	NA	55.8	1.4	2.3	2.2	NA	1.7
1981	8.1	15.2	25.4	8.7	57.0	1.5	2.4	2.3	1.7	1.8
1982	9.0	15.6	27.2	NA	57.3	1.6	2.5	2.4	NA	1.8
1983	9.4	15.7	29.7	8.4	60.0	1.7	2.5	2.5	1.6	1.8
1984	9.9	16.2	32.2	NA	63.5	1.7	2.5	2.6	NA	1.8
1985	10.5	17.6	35.8	9.2	66.6	1.8	2.6	2.8	1.6	1.8
1986	10.9	17.7	36.3	10.3	66.2	1.8	2.6	2.8	1.8	1.8
1987	10.9	18.4	38.8	NA	67.5	1.8	2.6	2.8	NA	1.8

NA = Not available.

[1] French data are based on gross domestic product; consequently, percentages may be slightly overstated compared to GNP.

[2] Foreign currency conversions to U.S. dollars are calculated with purchasing power parity exchange rates of the Organisation for Economic Co-operation and Development. See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: After 1977, U.S. data are budget authority instead of budget obligations.

SOURCES: NSF; Organisation for Economic Co-operation and Development (OECD); International Monetary Fund; and national sources.

See figure O-3 in Overview.

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Appendix table 4-21. Basic research expenditures as a percentage of total R&D: 1975-86

	France	West Germany	Japan	United Kingdom	United States
	Percent				
1975	NA	26	15	14	13
1976	NA	25	18	13	13
1977	21	25	17	13	13
1978	NA	22	18	13	13
1979	21	20	17	13	13
1980	21	21	15	13	13
1981	21	21	15	12	13
1982	21	21	15	NA	13
1983	21	20	15	NA	13
1984	20	NA	14	NA	12
1985	20	18	13	NA	12
1986	20	NA	13	NA	12
1987	NA	NA	NA	NA	12

NA = Not available.

Notes: Data for basic research are somewhat less reliable than those for total R&D expenditures. Each percentage generally relates to the total current R&D expenditures; for countries other than the United States, this may include some general university funds. Data for France and the United Kingdom are estimated for certain years.

SOURCES: NSF; Organisation for Economic Co-operation and Development (OECD); and national sources.

See figure 4-7.

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Appendix table 4-22. R&D appropriations, by socioeconomic objective: 1987

Objective	France	West Germany	Japan	United Kingdom	United States
	Percent				
Total	100.0	100.0	100.0	100.0	100.0
Agriculture, forestry, and fishing	3.6	2.0	4.0	4.2	2.3
Industrial development	10.6	15.3	4.8	8.7	0.2
Energy	6.7	8.7	23.2	3.5	3.6
Infrastructure	3.2	1.9	1.8	1.5	1.8
Transport and telecommunications	(1)	(1)	1.4	0.4	1.6
Urban and rural planning	(1)	(1)	0.4	1.2	0.2
Environmental protection	0.4	3.3	0.5	1.0	0.5
Health	3.6	3.2	2.4	4.3	11.9
Social development and services	2.7	2.3	1.0	1.5	1.0
Earth and atmosphere	1.4	1.9	1.0	1.7	0.7
Advancement of knowledge	26.6	43.8	50.8	20.2	3.6
Advancement of research	14.7	12.3	7.3	4.6	3.6
General university funds	12.0	31.5	43.5	15.6	(2)
Civil space	5.9	4.9	6.1	2.7	6.0
Defense	34.1	12.5	4.5	50.3	68.6
Not elsewhere classified	1.0	0.1	—	0.3	—

[1] Not separately available but included in subtotal.

[2] The United States does not have an equivalent to Europe's and Japan's general university funds.

Notes: Percentages may not add to 100 because of rounding. Additionally, because of general university funds and slight differences in accounting practices, the distribution of government budgets among socioeconomic objectives may not completely reflect the actual distribution of government-funded research in particular fields. Japanese data are based on science and technology budget data, which include items other than R&D. Nevertheless, such items are a small proportion of the budget, and the data may still be used as an approximate indicator of relative government emphasis on R&D by objective.

SOURCES: NSF; Organisation for Economic Co-operation and Development (OECD); and national sources for Japan.

See figure 4-8.

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Appendix table 4-23. Academic and academically related research, by field and country: 1987

Field	United Kingdom	West Germany	France	The Netherlands	United States	Japan
	Millions of dollars					
Total	2,821	3,979	3,211	960	14,897	3,738
Engineering	447	492	359	109	1,963	809
Physical sciences	550	1,012	955	207	2,324	543
Environmental sciences	187	181	172	27	859	137
Mathematics and computer sciences	211	151	175	34	593	88
Life sciences	865	1,459	1,116	318	7,285	1,261
Social sciences and psychology	187	195	146	100	754	145
Professional and vocational	157	203	67	82	490	369
Arts and humanities	178	254	218	82	411	358
Multidisciplinary[1]	39	32	3	1	218	28

[1] Research not elsewhere classified.

Note: Data are preliminary.

SOURCE: B.R. Martin, J. Irvine, and P. Isard, *International Trends in Government Funding of Academic and Related Research* (Sussex, England: Science Policy Research Unit, forthcoming).

See figure 4-9.

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Appendix table 4-24. Overview of state science and technology agencies

	S&T agency	Year created	Organizational structure	Role	Total funding FY 1987	Personnel FY 1988	Comments
					—Thousands of dollars—		
Arkansas	S&T Authority	1983	Independent state agency	Operating	2,750	12	(1)
California	Office of Competitive Technology	1989	Within state Department of Commerce	Operating	7,000 (3)	6 (3)	
Florida	High Technology & Industrial Council	1984	Within Office of the Governor	Advisory and operating	6,858	3	
Illinois	Governor's Commission on S&T	1983	Within state Department of Commerce & Community Affairs	Operating	6,175	10	
Massachusetts ...	Centers of Excellence Corporation	1985	Quasi-public organization	Operating	1,645	7	
Minnesota	Governor's Office of S&T	1983	Within state Department of Trade & Economic Development	Advisory and operating	2,609	11	
New Jersey	Commission on S&T	1985	Independent state agency	Operating	27,031	15	
New York	S&T Foundation	1963	Independent state agency	Operating	24,200	26	(2)
North Carolina ...	Board of S&T	1963	Within state Department of Administration	Advisory	1,418	4	(2)
Ohio	Thomas Edison Program	1983	Within state Department of Development	Advisory and operating	32,800	27	(2)
Oklahoma	Center for the Advancement of S&T	1987	Independent state agency	Operating	11,000 (4)	11	
Pennsylvania	Ben Franklin Partnership	1983	Within state Department of Commerce	Operating	36,475	7	
Texas	Office of Advanced Technology	1988	Within state Department of Commerce	Advisory	78 (4)	2	

[1] President of S&T Authority is unofficial science advisor to the governor.

[2] S&T agency director is governor's science advisor.

[3] Data are for FY 1989.

[4] Data are for FY 1988.

SOURCE: W.H. Lambright, E.M. Price, and A.H. Teich, *State S&T Indicators: An Exploratory Profile and Analysis* (Syracuse: Science and Technology Policy Center, forthcoming).

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Appendix table 4-25. State science and technology agency expenditures, by type of program: 1988[1]

	S&T agency	Agency-supported R&D			Scientific equipment and facilities	Technology transfer	Business development
		Total	Centers	Projects			
		Thousands of dollars					
Arkansas	S&T Authority	900		900		(2,3)	1,400
California	Office of Competitive Technology			(2)		(2)	
Florida	High Technology & Industry Council	3,850		3,850	1,300		1,500
Illinois	Governor's Commission on S&T					3,750	1,925
Massachusetts	Centers of Excellence Corp.	1,000		1,000	(2,3)		
Minnesota	Governor's Office of S&T					75	
New Jersey	Commission on S&T	14,884	12,034	2,850	6,982	1,650	780
New York	S&T Foundation	13,700	(2)	(2)		150	3,300
North Carolina	Board of S&T	400		400	(4)	100	
Ohio	Thomas Edison Program	17,500-22,500	15,000-20,000	2,580		1,875	2,700
Oklahoma	Center for Advancement of S&T	7,910	5,000	2,910	2,900	100	90
Pennsylvania	Ben Franklin Partnership	29,450	28,450	1,000	3,000[5]		4,000
Texas	Office of Advanced Technology	0					

[1] Data for Florida, Illinois, Massachusetts, and Pennsylvania are for FY 1987; all others are for FY 1988.

[2] Indicates presence of program(s); quantitative information not available.

[3] Support only; no funds.

[4] North Carolina ended its grants program in 1988.

[5] Data are for 1988. Does not include tax credit program.

SOURCE: W.H. Lambright, E.M. Price, and A.H. Teich, *State S&T Indicators: An Exploratory Profile and Analysis* (Syracuse: Science and Technology Policy Center, forthcoming).

Appendix table 4-26. R&D expenditures at doctorate-granting institutions, by source of funds and state: FYs 1978 and 1987

	Total		Federal Government		State and local governments		Industry		Institutional funds		All other sources	
	1978	1987	1978	1987	1978	1987	1978	1987	1978	1987	1978	1987
	Thousands of current dollars											
Total, all states .	4,540,256	11,930,997	3,004,930	7,230,217	406,509	1,003,449	166,271	764,088	610,068	2,109,547	352,478	823,696
Alabama	45,734	152,925	30,376	85,382	7,407	16,449	805	10,916	4,128	29,919	3,018	10,259
Alaska	39,367	30,192	26,591	14,454	1,225	2,919	1,105	1,217	9,472	11,056	974	546
Arizona	49,805	181,263	26,208	80,955	10,199	8,965	3,885	17,456	6,834	61,644	2,679	12,243
Arkansas	20,605	35,529	7,889	12,257	537	9,352	608	2,829	11,159	8,028	412	3,063
California	585,822	1,551,801	451,132	1,062,819	14,669	36,739	4,621	72,260	73,697	289,604	41,703	90,379
Colorado	86,832	185,699	65,048	136,003	5,206	8,771	3,216	8,728	7,575	17,682	5,787	14,515
Connecticut . . .	89,078	230,790	68,860	155,717	1,677	2,495	1,264	9,298	11,203	39,761	6,074	23,519
Delaware	11,575	31,681	6,787	13,662	409	1,995	1,546	3,659	2,201	10,117	632	2,248
District of Columbia . . .	45,506	85,470	35,282	62,968	127	484	2,187	4,192	2,957	11,642	4,953	6,184
Florida	107,629	252,303	59,642	128,868	5,189	13,341	3,829	20,730	20,575	72,419	18,394	16,945
Georgia	100,308	324,160	50,587	149,556	3,150	39,603	5,324	33,568	38,167	91,946	3,080	9,487
Hawaii	31,971	57,345	19,781	34,472	10,392	19,317	108	261	791	2,591	899	704
Idaho	13,442	24,779	5,898	8,988	4,720	8,314	472	2,899	1,552	4,436	800	142
Illinois	198,715	498,221	134,862	293,929	6,064	30,610	8,231	23,791	31,985	117,826	17,573	32,065
Indiana	79,991	188,086	55,131	111,413	6,791	15,772	4,272	17,203	10,947	37,627	2,850	6,071
Iowa	67,257	157,482	34,217	76,862	12,607	16,651	2,566	6,212	14,958	49,668	2,909	8,089
Kansas	38,169	93,931	15,497	37,386	11,477	20,031	1,101	5,433	8,925	27,607	1,169	3,474
Kentucky	33,148	78,008	19,647	30,778	7,468	10,841	2,782	6,715	2,760	26,545	491	3,129
Louisiana	57,230	148,563	18,829	54,367	18,206	31,850	1,445	7,154	11,816	42,639	6,934	12,553
Maine	11,022	16,952	5,392	7,787	551	315	750	2,051	3,691	5,740	638	1,059
Maryland	112,697	709,985	86,322	575,176	9,652	50,198	1,152	25,577	7,243	52,311	8,328	6,723
Massachusetts .	298,231	719,072	240,439	536,435	4,736	18,398	12,253	59,993	12,297	36,792	28,506	67,454
Michigan	171,295	396,786	99,129	208,017	12,744	30,343	10,328	25,072	34,758	103,788	14,336	29,566
Minnesota	94,706	222,381	53,265	109,003	10,665	37,287	2,851	11,056	20,539	39,371	7,386	25,664
Mississippi	29,563	57,622	10,721	22,492	9,419	16,667	793	4,170	7,641	8,897	989	5,396
Missouri	96,747	207,020	60,646	113,458	7,650	11,779	1,751	19,122	18,746	50,268	7,954	12,393
Montana	15,548	29,515	7,829	9,910	5,069	8,626	928	3,126	1,642	7,853	80	0
Nebraska	34,706	71,730	14,587	32,934	564	16,074	1,385	4,185	16,951	14,976	1,219	3,561
Nevada	10,500	28,070	4,227	13,608	3,233	1,912	1,025	4,065	1,752	7,824	263	661
New Hampshire	16,332	47,790	11,431	34,633	782	2,045	381	2,081	2,525	4,976	1,213	4,055
New Jersey . . .	68,387	215,580	40,846	96,048	6,960	37,489	3,505	11,910	12,932	55,142	4,144	14,991
New Mexico . . .	38,501	127,714	29,753	75,923	3,950	17,908	2,466	20,123	1,793	9,756	539	4,004
New York	482,103	1,130,142	334,141	769,178	22,397	52,771	17,851	62,499	57,956	137,090	49,758	108,604
North Carolina .	101,864	313,819	66,931	195,177	20,041	54,897	4,721	23,825	3,271	25,757	6,900	14,163
North Dakota . .	14,070	38,984	5,666	17,492	5,566	15,376	1,303	2,134	1,329	3,701	206	281
Ohio	136,891	328,772	80,770	193,061	11,781	34,903	6,351	22,360	17,892	46,924	20,097	31,524
Oklahoma	30,579	99,116	14,834	25,908	9,721	3,380	1,477	6,738	4,107	57,620	440	5,470
Oregon	56,129	132,255	34,975	81,932	10,680	18,645	2,823	4,059	2,562	12,936	5,089	14,683
Pennsylvania . .	239,892	604,832	163,399	387,038	5,113	24,229	14,231	61,299	37,065	76,500	20,084	55,766
Rhode Island . .	24,121	65,516	21,731	51,313	598	2,136	411	5,380	906	5,293	475	1,394
South Carolina .	23,452	95,811	10,998	34,350	8,207	14,061	1,084	6,184	1,744	37,110	1,419	4,106
South Dakota . .	8,789	11,513	3,936	5,188	346	4,700	438	482	3,942	875	127	268
Tennessee	52,063	144,144	35,630	80,820	6,352	25,789	3,414	13,792	4,702	19,232	1,965	4,511
Texas	266,945	810,993	162,254	403,298	38,444	89,468	7,121	46,295	31,637	172,935	27,489	98,997
Utah	52,279	120,878	38,542	81,355	5,510	13,412	2,481	5,734	3,213	16,178	2,533	4,199
Vermont	13,636	31,547	10,158	22,289	979	1,805	145	2,877	1,651	3,330	703	1,246
Virginia	62,765	206,621	42,388	116,654	10,629	36,400	4,886	18,103	3,440	27,110	1,422	8,354
Washington . . .	112,177	235,927	84,775	166,458	15,307	5,561	3,930	21,183	393	33,623	7,772	9,102
West Virginia . .	11,075	26,704	6,480	13,011	3,532	871	311	884	264	10,736	488	1,202
Wisconsin	125,463	303,188	77,018	171,704	21,922	49,818	3,153	11,992	14,832	45,196	8,538	24,478
Wyoming	10,160	17,316	6,155	8,701	184	1,129	1,162	1,216	2,649	6,176	10	94

(continued)

Appendix table 4-26. (Continued)

	Total		Federal Government		State and local governments		Industry		Institutional funds		All other sources	
	1978	1987	1978	1987	1978	1987	1978	1987	1978	1987	1978	1987
					Thousands of constant 1982 dollars							
Total, all states	6,330,530	10,090,491	4,189,808	6,114,866	566,800	848,654	231,834	646,218	850,625	1,784,123	491,464	696,631
Alabama	63,767	129,334	42,354	72,211	10,328	13,912	1,122	9,232	5,756	25,304	4,208	8,676
Alaska	54,890	25,535	37,076	12,224	1,708	2,469	1,541	1,029	13,207	9,350	1,358	462
Arizona	69,444	153,301	36,542	68,467	14,221	7,582	5,417	14,763	9,529	52,135	3,735	10,354
Arkansas	28,730	30,048	11,000	10,366	749	7,909	848	2,393	15,559	6,790	574	2,590
California	816,818	1,312,416	629,018	898,866	20,453	31,072	6,443	61,113	102,757	244,929	58,147	76,437
Colorado	121,071	157,053	90,697	115,023	7,259	7,418	4,484	7,382	10,562	14,954	8,069	12,276
Connecticut	124,202	195,188	96,012	131,696	2,338	2,110	1,762	7,864	15,620	33,627	8,469	19,891
Delaware	16,139	26,794	9,463	11,554	570	1,687	2,156	3,095	3,069	8,556	881	1,901
District of Columbia	63,450	72,285	49,194	53,254	177	409	3,049	3,545	4,123	9,846	6,906	5,230
Florida	150,068	213,382	83,160	108,988	7,235	11,283	5,339	17,532	28,688	61,247	25,647	14,331
Georgia	139,861	274,154	70,534	126,485	4,392	33,494	7,423	28,390	53,217	77,762	4,294	8,024
Hawaii	44,578	48,499	27,581	29,154	14,490	16,337	151	221	1,103	2,191	1,253	595
Idaho	18,742	20,957	8,224	7,601	6,581	7,031	658	2,452	2,164	3,752	1,115	120
Illinois	277,071	421,364	188,040	248,587	8,455	25,888	11,477	20,121	44,597	99,650	24,502	27,119
Indiana	111,532	159,071	76,870	94,226	9,469	13,339	5,956	14,549	15,264	31,823	3,974	5,134
Iowa	93,777	133,188	47,709	65,005	17,578	14,082	3,578	5,254	20,856	42,006	4,056	6,841
Kansas	53,219	79,441	21,608	31,619	16,003	16,941	1,535	4,595	12,444	23,348	1,630	2,938
Kentucky	46,219	65,974	27,394	26,030	10,413	9,169	3,879	5,679	3,848	22,450	685	2,646
Louisiana	79,796	125,645	26,253	45,980	25,385	26,937	2,015	6,050	16,475	36,061	9,668	10,617
Maine	15,368	14,337	7,518	6,586	768	266	1,046	1,735	5,146	4,855	890	896
Maryland	157,135	600,461	120,360	486,448	13,458	42,454	1,606	21,631	10,099	44,241	11,612	5,686
Massachusetts	415,827	608,146	335,247	453,683	6,603	15,560	17,084	50,738	17,146	31,116	39,746	57,048
Michigan	238,839	335,577	138,217	175,928	17,769	25,662	14,400	21,204	48,463	87,777	19,989	25,005
Minnesota	132,050	188,076	74,268	92,188	14,870	31,535	3,975	9,350	28,638	33,298	10,298	21,705
Mississippi	41,220	48,733	14,948	19,022	13,133	14,096	1,106	3,527	10,654	7,525	1,379	4,564
Missouri	134,895	175,085	84,559	95,956	10,666	9,962	2,441	16,172	26,138	42,514	11,090	10,481
Montana	21,679	24,962	10,916	8,381	7,068	7,295	1,294	2,644	2,289	6,642	112	0
Nebraska	48,391	60,665	20,339	27,854	786	13,594	1,931	3,539	23,635	12,666	1,700	3,012
Nevada	14,640	23,740	5,894	11,509	4,508	1,617	1,429	3,438	2,443	6,617	367	559
New Hampshire	22,772	40,418	15,938	29,290	1,090	1,730	531	1,760	3,521	4,208	1,691	3,429
New Jersey	95,353	182,324	56,952	81,231	9,704	31,706	4,887	10,073	18,031	46,636	5,778	12,678
New Mexico	53,682	108,013	41,485	64,211	5,508	15,145	3,438	17,019	2,500	8,251	752	3,386
New York	672,202	955,803	465,897	650,523	31,228	44,630	24,890	52,858	80,809	115,942	69,378	91,850
North Carolina	142,030	265,408	93,323	165,069	27,943	46,428	6,583	20,150	4,561	21,784	9,621	11,978
North Dakota	19,618	32,970	7,900	14,794	7,761	13,004	1,817	1,805	1,853	3,130	287	238
Ohio	190,869	278,055	112,619	163,279	16,426	29,519	8,855	18,911	24,947	39,685	28,021	26,661
Oklahoma	42,637	83,826	20,683	21,911	13,554	2,859	2,059	5,699	5,726	48,731	613	4,626
Oregon	78,261	111,853	48,766	69,293	14,891	15,769	3,936	3,433	3,572	10,940	7,096	12,418
Pennsylvania	334,484	511,529	227,829	327,333	7,129	20,491	19,842	51,843	51,680	64,699	28,003	47,163
Rhode Island	33,632	55,409	30,300	43,397	834	1,806	573	4,550	1,263	4,476	662	1,179
South Carolina	32,699	81,031	15,335	29,051	11,443	11,892	1,511	5,230	2,432	31,385	1,979	3,473
South Dakota	12,255	9,737	5,488	4,388	482	3,975	611	408	5,496	740	177	227
Tennessee	72,592	121,908	49,679	68,353	8,857	21,811	4,760	11,664	6,556	16,265	2,740	3,815
Texas	372,204	685,887	226,233	341,084	53,603	75,666	9,929	39,153	44,112	146,258	38,328	83,725
Utah	72,893	102,231	53,740	68,805	7,683	11,343	3,459	4,849	4,480	13,682	3,532	3,551
Vermont	19,013	26,680	14,163	18,851	1,365	1,527	202	2,433	2,302	2,816	980	1,054
Virginia	87,514	174,747	59,102	98,659	14,820	30,785	6,813	15,310	4,796	22,928	1,983	7,065
Washington	156,410	199,532	118,203	140,780	21,343	4,703	5,480	17,915	548	28,436	10,837	7,698
West Virginia	15,442	22,585	9,035	11,004	4,925	737	434	748	368	9,080	680	1,017
Wisconsin	174,934	256,417	107,387	145,217	30,566	42,133	4,396	10,142	20,680	38,224	11,905	20,702
Wyoming	14,166	14,645	8,582	7,359	257	955	1,620	1,028	3,694	5,223	14	79

Note: States will not sum to total because outlying areas and Puerto Rico are omitted.

SOURCES: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989); and unpublished tabulations.

See text table 4-4.

Appendix table 4-27. State R&D expenditures from state funds: 1977, 1987, and 1988

	1977	1987	1988
	Thousands of current dollars		
Alabama	385	1,097	1,047
Alaska	3,612	7,504	6,927
Arizona	429	643	670
Arkansas	211	1,110	1,027
California	23,659	49,521	53,305
Colorado	1,609	1,154	1,416
Connecticut	2,300	6,693	8,358
Delaware	202	2,003	2,511
Florida	7,374	14,450	13,736
Georgia	1,251	5,882	8,992
Hawaii	2,298	2,752	2,994
Idaho	595	486	961
Illinois	10,563	36,880	42,705
Indiana[1]	2,658	9,093	8,050
Iowa	1,179	5,914	7,800
Kansas	987	6,435	7,621
Kentucky	5,418	6,634	6,733
Louisiana	4,450	2,793	2,799
Maine	666	2,687	2,556
Maryland	7,606	158,028	172,148
Massachusetts	1,839	4,174	6,027
Michigan	4,797	8,010	15,192
Minnesota	2,987	4,780	6,160
Mississippi[1]	909	2,285	2,428
Missouri	634	842	955
Montana	1,783	6,132	3,166
Nebraska	252	1,493	1,483
Nevada[1]	199	1,457	1,806
New Hampshire	270	0	0
New Jersey	2,060	19,222	21,006
New Mexico	2,380	30,600	34,110
New York	64,298	179,538	194,336
North Carolina	5,076	12,370	10,782
North Dakota	1,077	781	906
Ohio	5,302	22,623	29,361
Oklahoma	643	0	604
Oregon	1,750	2,333	1,992
Pennsylvania	5,712	31,881	35,592
Rhode Island	491	1,163	1,024
South Carolina	2,189	4,296	4,616
South Dakota	872	1,179	1,471
Tennessee	518	1,889	2,313
Texas	4,914	11,947	10,952
Utah	803	916	968
Vermont	100	300	300
Virginia	2,959	11,589	10,475
Washington	2,637	1,999	12,480
West Virginia	227	287	324
Wisconsin	2,251	3,557	5,783
Wyoming	180	344	296
Total, all states	197,561	689,746	769,264

	1977	1987	1988
	Thousands of constant 1982 dollars		
Alabama	574	930	861
Alaska	5,389	6,359	5,697
Arizona	640	545	551
Arkansas	315	941	845
California	35,296	41,967	43,836
Colorado	2,400	978	1,164
Connecticut	3,431	5,672	6,873
Delaware	301	1,697	2,065
Florida	11,001	12,246	11,296
Georgia	1,866	4,985	7,395
Hawaii	3,428	2,332	2,462
Idaho	888	412	790
Illinois	15,759	31,254	35,119
Indiana[1]	3,965	7,706	6,620
Iowa	1,759	5,012	6,414
Kansas	1,472	5,453	6,267
Kentucky	8,083	5,622	5,537
Louisiana	6,639	2,367	2,302
Maine	994	2,277	2,102
Maryland	11,347	133,922	141,569
Massachusetts	2,744	3,537	4,956
Michigan	7,156	6,788	12,493
Minnesota	4,456	4,051	5,066
Mississippi[1]	1,356	1,936	1,997
Missouri	946	714	785
Montana	2,660	5,197	2,604
Nebraska	376	1,265	1,220
Nevada[1]	297	1,235	1,485
New Hampshire	403	0	0
New Jersey	3,073	16,290	17,275
New Mexico	3,551	25,932	28,051
New York	95,924	152,151	159,816
North Carolina	7,573	10,483	8,867
North Dakota	1,607	662	745
Ohio	7,910	19,172	24,146
Oklahoma	959	0	497
Oregon	2,611	1,977	1,638
Pennsylvania	8,522	27,018	29,270
Rhode Island	733	986	842
South Carolina	3,266	3,641	3,796
South Dakota	1,301	999	1,210
Tennessee	773	1,601	1,902
Texas	7,331	10,125	9,007
Utah	1,198	776	796
Vermont	149	254	247
Virginia	4,414	9,821	8,614
Washington	3,934	1,694	10,263
West Virginia	187	236	266
Wisconsin	1,851	2,925	4,756
Wyoming	148	283	243
Total, all states	294,735	584,531	632,618

[1] Expenditures only for the state's lead science and technology or research and development agency.

SOURCES: NSF, *Research and Development in State and Local Governments, Fiscal Year 1977*, NSF 79-327 (Washington, DC: NSF, 1979); and NSF, Division of Science Resources Studies, unpublished tabulations.

Appendix table 5-1. Expenditures for academic basic research, applied research, and development: 1960-89

	Total academic R&D	Basic research	Applied research	Development	Total academic R&D	Basic research	Applied research	Development	Basic research	Applied research	Development
	Millions of current dollars				Millions of constant 1982 dollars[1]				Percent of total		
1960	646	433	179	34	2,077	1,392	575	109	67.0	27.7	5.3
1961	763	536	192	35	2,427	1,705	611	111	70.2	25.2	4.6
1962	904	659	205	40	2,825	2,059	641	125	72.9	22.7	4.4
1963	1,081	814	227	40	3,318	2,498	697	123	75.3	21.0	3.7
1964	1,275	1,003	232	40	3,858	3,035	702	121	78.7	18.2	3.1
1965	1,474	1,138	279	57	4,367	3,372	827	169	77.2	18.9	3.9
1966	1,715	1,303	328	84	4,937	3,751	944	242	76.0	19.1	4.9
1967	1,921	1,457	374	90	5,347	4,055	1,041	250	75.8	19.5	4.7
1968	2,149	1,649	404	96	5,778	4,434	1,086	258	76.7	18.8	4.5
1969	2,225	1,711	407	107	5,676	4,365	1,038	273	76.9	18.3	4.8
1970	2,335	1,796	427	112	5,629	4,330	1,029	270	76.9	18.3	4.8
1971	2,500	1,914	474	112	5,726	4,384	1,086	257	76.6	19.0	4.5
1972	2,630	2,022	524	84	5,710	4,390	1,138	182	76.9	19.9	3.2
1973	2,884	2,053	713	118	5,965	4,246	1,475	244	71.2	24.7	4.1
1974	3,023	2,154	736	133	5,796	4,130	1,411	255	71.3	24.3	4.4
1975	3,409	2,410	851	148	5,927	4,190	1,479	257	70.7	25.0	4.3
1976	3,729	2,549	1,016	164	6,007	4,106	1,637	264	68.4	27.2	4.4
1977	4,067	2,800	1,067	200	6,067	4,177	1,592	298	68.8	26.2	4.9
1978	4,625	3,176	1,213	236	6,449	4,428	1,691	329	68.7	26.2	5.1
1979	5,361	3,612	1,465	284	6,882	4,637	1,881	365	67.4	27.3	5.3
1980	6,061	4,024	1,695	342	7,152	4,749	2,000	404	66.4	28.0	5.6
1981	6,845	4,589	1,868	388	7,344	4,923	2,004	416	67.0	27.3	5.7
1982	7,324	4,883	2,018	423	7,324	4,883	2,018	423	66.7	27.6	5.8
1983	7,883	5,324	2,116	443	7,563	5,108	2,030	425	67.5	26.8	5.6
1984	8,623	5,731	2,404	488	7,970	5,297	2,222	451	66.5	27.9	5.7
1985	9,694	6,556	2,552	586	8,692	5,878	2,288	525	67.6	26.3	6.0
1986	10,926	7,512	2,699	715	9,536	6,556	2,356	624	68.8	24.7	6.5
1987	12,082	8,301	3,014	767	10,218	7,020	2,549	649	68.7	24.9	6.3
1988 (est.)	13,000	8,900	3,280	820	10,679	7,311	2,694	674	68.5	25.2	6.3
1989 (est.)	13,900	9,500	3,530	870	10,999	7,517	2,793	688	68.3	25.4	6.3

[1] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: NSF, *National Patterns of R&D Resources: 1989*, NSF 89-308 (Washington, DC: NSF, 1989).

See figure 5-1.

Appendix table 5-2. Support for academic R&D by sector: 1960-87

Fiscal year	Total	Federal Government	State/local government	Industry	Academic institutions' funds	All other sources
	Millions of current dollars					
1960	646	405	85	40	64	52
1961	763	500	95	40	70	58
1962	904	613	106	40	79	66
1963	1,081	760	118	41	89	73
1964	1,275	917	132	40	103	83
1965	1,474	1,073	143	41	124	93
1966	1,715	1,261	156	42	148	108
1967	1,921	1,409	164	48	181	119
1968	2,149	1,572	172	55	218	132
1969	2,225	1,600	197	60	223	145
1970	2,335	1,647	219	61	243	165
1971	2,500	1,724	255	70	274	177
1972	2,630	1,795	269	74	305	187
1973	2,884	1,985	295	84	318	202
1974	3,022	2,032	308	95	368	219
1975	3,409	2,288	332	113	417	259
1976	3,729	2,512	364	123	446	285
1977	4,067	2,726	374	139	514	314
1978[1]	4,625	3,059	412	170	625	359
1979	5,359	3,593	470	194	726	374
1980	6,062	4,096	491	238	835	401
1981	6,845	4,561	546	293	1,009	436
1982	7,324	4,759	613	339	1,122	491
1983	7,884	4,980	622	388	1,315	579
1984	8,623	5,425	684	474	1,424	617
1985	9,695	6,064	745	559	1,632	694
1986	10,926	6,713	911	692	1,877	732
1987	12,082	7,326	1,019	777	2,126	834
1988 (est.)[1]	13,000	7,800	1,124	850	2,346	880
1989 (est.)[1]	13,900	8,250	1,231	920	2,569	930
	Millions of constant 1982 dollars[2]					
1960	2,077	1,302	273	129	206	167
1961	2,427	1,590	302	127	223	184
1962	2,825	1,916	331	125	247	206
1963	3,318	2,333	362	126	273	224
1964	3,858	2,775	399	121	312	251
1965	4,367	3,179	424	121	367	276
1966	4,937	3,630	449	121	426	311
1967	5,347	3,922	456	134	504	331
1968	5,778	4,227	462	148	586	355
1969	5,676	4,082	503	153	569	370
1970	5,629	3,971	528	147	586	398
1971	5,726	3,949	584	160	628	405
1972	5,710	3,897	584	161	662	406
1973	5,965	4,105	610	174	658	418
1974	5,794	3,896	590	182	706	420
1975	5,927	3,978	577	196	725	450
1976	6,007	4,046	586	198	718	459
1977	6,067	4,067	558	207	767	468
1978[1]	6,449	4,265	574	237	871	501
1979	6,879	4,612	603	249	932	480

(continued)

Appendix table 5-2. (Continued)

Fiscal year	Total	Federal Government	State/local government	Industry	Academic institutions' funds	All other sources
			Millions of constant 1982 dollars[2]			
1980	7,154	4,834	579	281	985	473
1981	7,344	4,893	586	314	1,083	468
1982	7,324	4,759	613	339	1,122	491
1983	7,564	4,778	597	372	1,262	556
1984	7,970	5,014	632	438	1,316	570
1985	8,693	5,437	668	501	1,463	622
1986	9,536	5,859	795	604	1,638	639
1987	10,218	6,196	862	657	1,798	705
1988 (est.)[1]	10,679	6,408	923	698	1,927	723
1989 (est.)[1]	10,999	6,528	974	728	2,033	736
			Percent			
1960	100	62.7	13.2	6.2	9.9	8.0
1961	100	65.5	12.5	5.2	9.2	7.6
1962	100	67.8	11.7	4.4	8.7	7.3
1963	100	70.3	10.9	3.8	8.2	6.8
1964	100	71.9	10.4	3.1	8.1	6.5
1965	100	72.8	9.7	2.8	8.4	6.3
1966	100	73.5	9.1	2.4	8.6	6.3
1967	100	73.3	8.5	2.5	9.4	6.2
1968	100	73.2	8.0	2.6	10.1	6.1
1969	100	71.9	8.9	2.7	10.0	6.5
1970	100	70.5	9.4	2.6	10.4	7.1
1971	100	69.0	10.2	2.8	11.0	7.1
1972	100	68.3	10.2	2.8	11.6	7.1
1973	100	68.8	10.2	2.9	11.0	7.0
1974	100	67.2	10.2	3.1	12.2	7.2
1975	100	67.1	9.7	3.3	12.2	7.6
1976	100	67.4	9.8	3.3	12.0	7.6
1977	100	67.0	9.2	3.4	12.6	7.7
1978[1]	100	66.1	8.9	3.7	13.5	7.8
1979	100	67.0	8.8	3.6	13.5	7.0
1980	100	67.6	8.1	3.9	13.8	6.6
1981	100	66.6	8.0	4.3	14.7	6.4
1982	100	65.0	8.4	4.6	15.3	6.7
1983	100	63.2	7.9	4.9	16.7	7.3
1984	100	62.9	7.9	5.5	16.5	7.2
1985	100	62.5	7.7	5.8	16.8	7.2
1986	100	61.4	8.3	6.3	17.2	6.7
1987	100	60.6	8.4	6.4	17.6	6.9
1988 (est.)[1]	100	60.0	8.6	6.5	18.0	6.8
1989 (est.)[1]	100	59.4	8.9	6.6	18.5	6.7

[1] Relative amounts of funds from state and local governments and from academic institutions are estimated from previous year's ratio.

[2] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987,* NSF 89-311 (Washington, DC: NSF, 1989); NSF, *National Patterns of R&D Resources: 1989,* NSF 89-308 (Washington, DC: NSF, 1989).

See figure O-20 in Overview.

Appendix table 5-3. Sources of R&D funds at private and public academic institutions, by sector: 1980 and 1987

	Source of funds					
Type of institution	Total	Federal Government	State and local government	Industry	Academic institutions' funds	Other sources
	Thousands of dollars					
1980						
Private	2,223,758	1,745,892	45,011	94,899	172,599	165,357
Public	3,837,820	2,350,603	446,034	143,094	662,449	235,640
1987						
Private	4,263,274	3,167,682	95,214	282,697	379,181	338,501
Public	7,818,257	4,158,028	923,675	494,199	1,746,975	495,380
	Percent					
1980						
Private	100.0	78.5	2.0	4.3	7.8	7.4
Public	100.0	61.2	11.6	3.7	17.3	6.1
1987						
Private	100.0	74.3	2.2	6.6	8.9	7.9
Public	100.0	53.2	11.8	6.3	22.3	6.3

SOURCE: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989).

Science & Engineering Indicators—1989

Appendix table 5-4. Types of Federal obligations for academic science and engineering: 1967-87

	Total	R&D	R&D plant	Facilities for S/E instruction	Fellowships, traineeships, and training grants	General support for S/E	Other S/E activities
				Thousands of current dollars			
1967	2,323,795	1,301,242	111,309	(1)	447,236	(1)	464,008
1968	2,349,817	1,398,305	96,148	(1)	440,895	(1)	414,469
1969	2,361,399	1,474,681	54,516	(1)	436,270	(1)	395,932
1970	2,187,579	1,446,618	44,778	(1)	429,408	(1)	266,775
1971	2,343,129	1,551,391	29,942	28,729	421,029	99,669	212,369
1972	2,599,111	1,853,085	36,917	26,341	387,888	83,288	211,592
1973	2,464,362	1,870,690	43,338	13,372	287,210	38,964	210,788
1974	2,736,984	2,085,204	29,009	3,506	326,600	86,974	205,691
1975	2,805,783	2,246,088	44,787	5,026	201,273	46,353	262,256
1976	2,959,656	2,430,970	23,899	3,210	174,871	74,483	252,223
1977	3,351,337	2,803,017	36,471	3,282	184,671	75,928	247,968
1978	3,959,832	3,385,770	34,328	4,906	205,925	74,398	254,505
1979	4,472,659	3,873,514	32,068	6,743	204,866	92,483	262,985
1980	4,790,972	4,160,543	37,780	3,776	210,121	91,541	287,211
1981	5,062,856	4,410,931	27,694	4,563	205,448	92,721	321,499
1982	5,179,610	4,554,475	31,200	829	176,582	80,137	336,387
1983	5,680,631	5,024,330	37,547	2,552	189,616	94,847	331,769
1984	6,308,014	5,448,821	49,764	1,889	194,895	112,588	500,057
1985	7,257,862	6,246,181	113,932	4,947	253,082	119,171	520,549
1986	7,430,775	6,456,646	105,827	4,990	246,196	111,130	505,986
1987	8,565,038	7,240,090	229,875	13,722	290,942	236,933	553,476
				Thousands of constant 1982 dollars[2]			
1967	6,467,562	3,621,603	309,794	(1)	1,244,743	(1)	1,291,422
1968	6,318,411	3,759,895	258,532	(1)	1,185,520	(1)	1,114,464
1969	6,023,977	3,761,941	139,071	(1)	1,112,934	(1)	1,010,031
1970	5,273,816	3,487,507	107,951	(1)	1,035,217	(1)	643,141
1971	5,366,764	3,553,346	68,580	65,802	964,336	228,284	486,415
1972	5,642,881	4,023,198	80,150	57,188	842,136	180,825	459,383
1973	5,096,922	3,869,059	89,634	27,657	594,023	80,587	435,963
1974	5,247,285	3,997,707	55,615	6,722	626,150	166,745	394,346
1975	4,877,926	3,904,882	77,863	8,738	349,918	80,586	455,939
1976	4,767,487	3,915,867	38,497	5,171	281,687	119,979	406,287
1977	4,999,757	4,181,735	54,410	4,896	275,505	113,275	369,936
1978	5,521,238	4,720,817	47,864	6,840	287,124	103,734	354,859
1979	5,741,539	4,972,418	41,166	8,656	262,986	118,720	337,593
1980	5,653,731	4,909,775	44,583	4,456	247,960	108,026	338,932
1981	5,431,666	4,732,251	29,711	4,895	220,414	99,475	344,919
1982	5,179,610	4,554,475	31,200	829	176,582	80,137	336,387
1983	5,450,092	4,820,426	36,023	2,448	181,921	90,998	318,305
1984	5,830,496	5,036,344	45,997	1,746	180,141	104,065	462,203
1985	6,507,542	5,600,449	102,154	4,436	226,918	106,851	466,735
1986	6,485,229	5,635,055	92,361	4,355	214,868	96,989	441,601
1987	7,243,774	6,123,215	194,414	11,605	246,061	200,383	468,095

[1] Not separately classified; included under "other S/E activities."

[2] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: NSF, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions: Fiscal Year 1987*, NSF 88-330 (Washington, DC: NSF, 1988).

See figure 5-2.

Appendix table 5-5. Federal obligations for academic research and development, by agency: 1969-89

	Total agencies	NIH	NSF	DOD	NASA	DOE[1]	USDA	Other agencies
	Millions of current dollars							
1969	1,529	535	213	263	99	101	62	256
1970	1,476	518	228	216	111	100	65	238
1971	1,645	603	267	211	119	94	72	279
1972	1,904	756	362	217	134	85	87	263
1973	1,917	761	374	204	131	83	94	270
1974	2,214	1,027	389	197	125	94	95	287
1975	2,411	1,077	435	203	131	132	108	325
1976	2,552	1,185	437	240	124	145	120	301
1977	2,905	1,311	511	273	118	188	140	364
1978	3,375	1,493	537	383	127	240	186	409
1979	3,889	1,765	617	438	139	260	200	470
1980	4,263	1,888	685	495	158	285	216	536
1981	4,466	1,984	702	573	171	300	243	493
1982	4,605	2,026	715	664	186	277	255	482
1983	4,966	2,264	783	724	189	297	275	434
1984	5,565	2,560	880	830	222	321	261	491
1985	6,299	2,918	1,002	940	255	357	293	534
1986	6,555	3,033	994	1,074	305	328	267	554
1987	7,354	3,639	1,096	1,017	310	387	280	626
1988 (est.)	7,771	3,891	1,122	1,067	340	410	305	637
1989 (est.)	8,167	4,028	1,384	1,129	351	395	265	615
	Millions of constant 1982 dollars[2]							
1969	3,901	1,365	543	671	253	258	158	653
1970	3,558	1,249	550	521	268	241	157	574
1971	3,768	1,381	612	483	273	215	165	639
1972	4,134	1,641	786	471	291	185	189	571
1973	3,965	1,574	774	422	271	172	194	558
1974	4,245	1,969	746	378	240	180	182	550
1975	4,192	1,872	756	353	228	229	188	565
1976	4,111	1,909	704	387	200	234	193	485
1977	4,334	1,956	762	407	176	280	209	543
1978	4,706	2,082	749	534	177	335	259	570
1979	4,992	2,266	792	562	178	334	257	603
1980	5,031	2,228	808	584	186	336	255	633
1981	4,791	2,129	753	615	183	322	261	529
1982	4,605	2,026	715	664	186	277	255	482
1983	4,764	2,172	751	695	181	285	264	416
1984	5,144	2,366	813	767	205	297	241	454
1985	5,648	2,616	898	843	229	320	263	479
1986	5,721	2,647	868	937	266	286	233	484
1987	6,219	3,077	927	860	262	327	237	529
1988 (est.)	6,384	3,196	921	876	279	337	251	523
1989 (est.)	6,462	3,187	1,095	893	278	313	209	487

(continued)

Appendix table 5-5. (Continued)

	Total agencies	NIH	NSF	DOD	NASA	DOE[1]	USDA	Other agencies
	Percent							
1969	100	35.0	13.9	17.2	6.5	6.6	4.1	16.7
1970	100	35.1	15.4	14.6	7.5	6.8	4.4	16.1
1971	100	36.7	16.2	12.8	7.2	5.7	4.4	17.0
1972	100	39.7	19.0	11.4	7.0	4.5	4.6	13.8
1973	100	39.7	19.5	10.6	6.8	4.3	4.9	14.1
1974	100	46.4	17.6	8.9	5.6	4.2	4.3	13.0
1975	100	44.7	18.0	8.4	5.4	5.5	4.5	13.5
1976	100	46.4	17.1	9.4	4.9	5.7	4.7	11.8
1977	100	45.1	17.6	9.4	4.1	6.5	4.8	12.5
1978	100	44.2	15.9	11.3	3.8	7.1	5.5	12.1
1979	100	45.4	15.9	11.3	3.6	6.7	5.1	12.1
1980	100	44.3	16.1	11.6	3.7	6.7	5.1	12.6
1981	100	44.4	15.7	12.8	3.8	6.7	5.4	11.0
1982	100	44.0	15.5	14.4	4.0	6.0	5.5	10.5
1983	100	45.6	15.8	14.6	3.8	6.0	5.5	8.7
1984	100	46.0	15.8	14.9	4.0	5.8	4.7	8.8
1985	100	46.3	15.9	14.9	4.0	5.7	4.7	8.5
1986	100	46.3	15.2	16.4	4.7	5.0	4.1	8.5
1987	100	49.5	14.9	13.8	4.2	5.3	3.8	8.5
1988 (est.)	100	50.1	14.4	13.7	4.4	5.3	3.9	8.2
1989 (est.)	100	49.3	16.9	13.8	4.3	4.8	3.2	7.5

[1] Atomic Energy Commission, 1969-73; Energy Research and Development Administration, 1974-76; Department of Energy 1977-89.

[2] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: Percentages may not add to 100 because of rounding.

SOURCES: NSF, *Federal Funds for Research and Development: Fiscal Years 1987, 1988, and 1989*, NSF 89-304 (Washington, DC: NSF, 1989); NSF, *Federal Funds for Reseach and Development, Detailed Historical Tables: Fiscal Years 1955-1985*, unpublished.

Science & Engineering Indicators—1989

Appendix table 5-6. R&D expenditures at the top 100 universities and colleges, by source of funds: 1987

Academic Institutions' ranking	Total	Federal Government	State and local government	Industry	Institutional funds	Other
			Thousands of dollars			
Total, all institutions	12,081,531	7,325,710	1,018,889	776,895	2,126,156	833,881
1 Johns Hopkins University	510,896	476,290	1,998	7,755	19,205	5,648
2 Mass Inst of Technology	264,416	206,785	3,501	35,064	5,165	13,901
3 Univ of Wis-Madison	254,493	149,665	44,864	8,586	36,178	15,200
4 Cornell University	244,840	144,604	34,674	17,169	26,385	22,008
5 Stanford University	240,885	204,386	226	10,979	12,001	13,293
6 University of Michigan	224,890	137,558	3,123	14,451	55,345	14,413
7 University of Minnesota	222,381	109,003	37,287	11,056	39,371	25,664
8 Texas A&M University	219,853	75,432	59,961	13,398	65,038	6,024
9 Univ of Cal Los Angeles	188,831	130,763	4,213	14,360	27,308	12,187
10 Univ of Ill Urbana	188,682	104,420	23,677	11,414	43,275	5,896
Total, 1st 10 Institutions	2,560,167	1,738,906	213,524	144,232	329,271	134,234
11 University of Washington	187,062	145,184	4,064	18,564	14,201	5,049
12 Univ of Cal San Diego	183,047	142,751	3,203	5,902	18,784	12,407
13 Univ of Cal Berkeley	175,273	108,828	3,996	6,580	47,861	8,008
14 Univ of Cal San Francisco	169,436	117,302	6,571	4,008	22,249	19,306
15 Harvard University	169,074	119,955	845E	7,778E	12,343E	28,153
16 Univ of Texas at Austin	168,931	88,395	7,345	3,161	51,240	18,790
17 Pennsylvania State Univ	165,841	94,326	7,981	20,114	43,141	279
18 Univ of Pennsylvania	158,334	111,185	2,353	2,536	15,924	26,336
19 Columbia Univ Main Div	149,904	133,018	1,000	3,915	2,837	9,134
20 Yale University	145,818	116,943	298	5,563	8,956	14,058
Total, 1st 20 Institutions	4,232,887	2,916,793	251,180	222,353	566,807	275,754
21 Univ of Cal Davis	143,798	56,622	7,786	5,324	66,832	7,234
22 University of Arizona	138,726	65,024	2,871	11,638	50,400	8,793
23 Univ of Southern Cal	134,995	101,749	1,517	9,999	21,730	0
24 Univ of Md College Park	126,239	55,194	34,254E	10,149E	26,642E	0
25 University of Georgia	124,442	35,261	34,828	4,982	48,550	821
26 Ohio State University	123,246	58,555	19,729	9,278	19,022	16,662
27 Georgia Institute of Tech	120,342	63,132	1,447	23,628	32,135	0
28 University of Colorado	112,276	83,144	1,163	4,502	12,407	11,060
29 Michigan State University	111,810	44,989	20,095	3,137	33,234	10,355
30 Purdue University	107,131	56,302	15,213	9,579	23,591	2,446
Total, 1st 30 Institutions	5,475,892	3,536,765	390,083	314,569	901,350	333,125
31 University of Florida	104,245	49,311	6,965	9,404	31,119	7,446
32 Washington University	103,419	77,757	541	12,016	7,397	5,708
33 NC State Univ at Raleigh	102,647	33,662	41,835	11,748	13,236	2,166
34 Louisiana State Univ	102,070	31,089	29,941	1,481	32,283	7,276
35 University of Rochester	101,598	80,322	5,018	6,267	1,909	8,082
36 New York University	98,924	76,126	853	3,036	10,581	8,328
37 Rutgers The St Univ of NJ	94,555	27,178	23,182	3,087	37,275	3,833
38 Univ of NC at Chapel Hill	93,754	72,529	11,480	509	5,432	3,804
39 University of Chicago	91,879	75,889	394	1,812	7,229	6,555
40 Baylor Col of Medicine	90,179	49,834	2,520	3,860	9,861	24,104
Total, 1st 40 Institutions	6,459,162	4,110,462	512,812	367,789	1,057,672	410,427
41 Duke University	89,556	67,925	693	8,085	6,941	5,912
42 Northwestern University	88,920	49,286	357	3,101	29,597	6,579
43 California Inst of Tech	86,565	71,086	664	3,436	4,540	6,839
44 University of Pittsburgh	84,183	62,060	918	6,547	5,655	9,003
45 Carnegie-Mellon Univ	83,763	53,817	5,741	16,130	1,212	6,863
46 University of Connecticut	81,575	36,884	2,193	3,729	29,499	9,270
47 Va Polytech Inst & St U	80,552	32,129	27,253	7,010	13,039	1,121
48 Univ of Massachusetts	79,814	44,256	8,043	8,560	15,661	3,294
49 Oregon State University	79,715	46,774	18,242	1,890	3,965	8,844
50 University of Iowa	79,090	57,159	470	2,615	15,112	3,734
Total, 1st 50 Institutions	7,292,895	4,631,838	577,386	428,892	1,182,893	471,886

(continued)

Academic Institutions' ranking	Total	Federal Government	State and local government	Industry	Institutional funds	Other
	Thousands of dollars					
51 Iowa St U of Sci & Tech	78,351	19,682	16,181	3,597	34,536	4,355
52 Yeshiva University	73,773	59,768	0	0	7,285	6,720
53 Univ Alabama Birmingham	72,692	54,534	2,038	4,544	5,827	5,749
54 Case Western Reserve Univ	70,850	53,580	2,005	3,433	5,808	6,024
55 SUNY at Buffalo	70,474	51,212	2,349	779	10,991	5,143
56 University of Utah	68,194	54,226	2,703	2,268	5,596	3,401
57 Rockefeller University	66,760	37,983	244	3,476	14,039	11,018
58 U Texas System Cancer Ctr	65,417	22,162	0	0	26,700	16,555
59 Indiana University	65,341	44,211	452	4,597	12,500	3,581
60 University of Miami	65,158	38,052	1,306	7,300	12,573	5,927
Total, 1st 60 Institutions	7,989,905	5,067,248	604,664	458,886	1,318,748	540,359
61 Princeton University	65,089	43,505	974	4,122	11,997	4,491
62 Univ of Ill Chicago	64,701	34,570	2,102	1,728	19,238	7,063
63 University of Virginia	63,861	41,267	4,627	3,260	9,663	5,044
64 U Tex Hlth Sci Ctr Dallas	62,907	45,382	216	5,566	53	11,690
65 Univ of Missouri Columbia	61,212	20,250	10,292	4,206	22,351	4,113
66 U Tennessee Knoxville	60,096	28,752	16,713	3,440	10,398	793
67 Emory University	58,889	36,698	2,623	3,350	9,171	7,047
68 New Mexico State Univ	58,672	37,904	9,307	9,847	1,086	528
69 Boston University	58,299	49,406	1,865	2,276	0	4,752
70 Univ of Hawaii-Manoa	57,345	34,472	19,317	261	2,591	704
Total, 1st 70 Institutions	8,600,976	5,439,454	672,700	496,942	1,405,296	586,584
71 Univ of Nebraska-Lincoln	56,066	24,512	15,182	1,938	12,818	1,616
72 University of Kentucky	55,042	26,261	5,237	6,312	17,232	0
73 SUNY at Stony Brook	54,219	39,445	1,848	1,269	8,003	3,654
74 University of Cincinnati	53,804	32,044	2,839	2,299	11,240	5,382
75 Colorado State University	52,619	38,961	6,357	1,178	3,302	2,821
76 Univ of Cal Irvine	51,691	38,138	1,411	4,722	4,903	2,517
77 Univ of Cal Riverside	51,158	15,001	2,451	1,955	29,972	1,779
78 University of Kansas	50,603	22,941	2,295	3,259	20,656	1,452
79 Washington State Univ	48,865	21,274	1,497	2,619	19,422	4,053
80 Woods Hole Ocngrphic Inst	48,061	42,239	2	667	730	4,423
Total, 1st 80 Institutions	9,123,104	5,740,270	711,819	523,160	1,533,574	614,281
81 Auburn University	48,045	13,446	12,349	3,112	14,894	4,244
82 Oklahoma State University	47,420	9,575	2,127	3,170	30,509	2,039
83 Tufts University	46,497	37,148	2,348	914E	58E	6,029
84 Clemson University	46,495	9,016	13,056	3,105	20,030	1,288
85 Florida State University	46,420	21,416	1,549	280	21,850	1,325
86 CUNY Mt Sinai Sch of Med	46,137	31,024	347	2,870	2,655	9,241
87 Univ of Md Balt Prof Sch	45,523	26,244	11,627	7,652	0	0
88 University of Oklahoma	45,350	14,453	1,124	2,026	24,434	3,313
89 University of New Mexico	45,333	29,096	3,342	4,858	4,744	3,293
90 Vanderbilt University	43,589	31,343	922	5,313	3,029	2,982
Total, 1st 90 Institutions	9,583,913	5,963,031	760,610	556,460	1,655,777	648,035
91 Univ of Cal Santa Barbara	42,704	32,856	1,489	1,970	3,842	2,547
92 Utah State University	41,343	22,109	9,879	1,316	7,467	572
93 Virginia Commonwlth Univ	41,016	31,612	1,347	5,400	2,565	92
94 Kans St U—Ag & App Sci	40,587	13,270	17,511	1,515	6,652	1,639
95 Mississippi State Univ	40,405	12,387	15,496	2,823	5,690	4,009
96 Wayne State University	39,335	16,927	3,592	2,761	11,572	4,483
97 Arizona State University	38,763	14,009	5,850	5,575	9,879	3,450
98 Tulane University	38,393	21,836	160	4,945	7,298	4,154
99 Brown University	38,110	32,024	75	4,250	550	1,211
100 Georgetown University	35,981	24,477	112	2,536	5,953	2,903
Total, 1st 100 Institutions	9,980,550	6,184,538	816,121	589,551	1,717,245	673,095

Notes: Numbers followed by "E" are estimated; "0" means no report or a report of no funds received.

SOURCE: NSF, *Academic Science/Engineering: R&D funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989).

See text table 5-1.

Appendix table 5-7. Academic R&D support derived from industry among the top 200 R&D-performing campuses: FY 1987

Industrial share[1]	Campus	Thousands of industry dollars	Industrial share	Campus	Thousands of industry dollars	Industrial share
	Rank 1-25 ($511-$124 million)[2]			Rank 26-50 ($123-$79 million)[2]		
	Average industrial share[3]		5.5	Average industrial share[3]		6.7
≥10%	Mass Inst of Tech	35,064	13.3	Georgia Inst of Tech	23,628	19.6
	Penn State Univ	20,114	12.1	Carnegie-Mellon Univ	16,130	19.3
				Washington University	12,016	11.6
				NC State at Univ-Raleigh	11,748	11.4
				Univ of Massachusetts	8,560	10.7
5.0-9.9%	Univ of Washington	18,564	9.9	University of Florida	9,404	9.0
	Univ of Arizona	11,638	8.4	Duke University	8,085	9.0
	Univ of Md College Park[5]	10,149	8.0	Purdue University	9,579	8.9
	Univ of Cal Los Angeles	14,360	7.6	VA Polytech Inst & St U	7,010	8.7
	Univ of Southern Cal	9,999	7.4	University of Pittsburgh	6,547	7.8
	Cornell University	17,169	7.0	Ohio State University	9,278	7.5
	Univ of Michigan	14,451	6.4	University of Rochester	6,267	6.2
	Texas A&M Univ	13,398	6.1			
	Univ of Ill Urbana	11,414	6.0			
	University of Minnesota	11,056	5.0			
3.0-5.9%	Stanford University	10,979	4.6	Univ of Connecticut	3,729	4.6
	Harvard University[5]	7,778	4.6	Baylor Col of Medicine	3,860	4.3
	University of Georgia	4,982	4.0	Univ of Colorado	4,502	4.0
	Univ of Cal Berkeley	6,580	3.8	California Inst of Tech	3,436	4.0
	Yale University	5,563	3.8	Northwestern Univ	3,101	3.5
	Univ of Cal Davis	5,324	3.7	Rutgers St Univ of NJ	3,087	3.3
	Univ of Wis-Madison	8,586	3.4	University of Iowa	2,615	3.3
	Univ of Cal San Diego	5,902	3.2	New York University	3,036	3.1
<3.0%	Columbia Univ Main Div	3,915	2.6	Michigan State Univ	3,137	2.8
	Univ of Cal San Fran	4,008	2.4	Oregon State Univ	1,890	2.4
	Univ of Texas at Austin	3,161	1.9	University of Chicago	1,812	2.0
	Univ of Pennsylvania	2,536	1.6	Louisiana State Univ	1,481	1.5
	Johns Hopkins Univ	7,755	1.5	Univ of NC-Chapel Hill	509	0.1
	Rank 51-75 ($78-53 million)[2]			Rank 76-100 ($52-$36 million)[2]		
	Average industrial share[3]		5.6	Average industrial share[3]		7.3
≥10%	New Mexico State Univ	9,847	16.8	Univ of Md Balt Prof Sch	7,652	16.8
	University of Kentucky	6,312	11.5	Arizona State University	5,575	14.4
	University of Miami	7,300	11.2	Virginia Commonwlth Univ	5,400	13.2
				Tulane University	4,945	12.9
				Vanderbilt University	5,313	12.2
				Brown University	4,250	11.2
				University of New Mexico	4,858	10.7
5.0-9.9%	U TX Hlth Sci Ctr Dallas	5,566	8.8	Univ of Cal Irvine	4,722	9.1
	Indiana University	4,597	7.0	Georgetown University	2,536	7.0
	Univ of Missouri Columbia	4,206	6.9	Mississippi State Univ	2,823	7.0
	Princeton University	4,122	6.3	Wayne State University	2,761	7.0
	Univ Alabama Birmingham	4,544	6.3	Clemson University	3,105	6.7
	U Tennessee Knoxville	3,440	5.7	Oklahoma State Univ	3,105	6.7
	Emery University	3,350	5.7	Auburn University	3,112	6.5
	Rockefeller University	3,476	5.2	University of Kansas	3,259	6.4
	University of Virginia	3,260	5.1	CUNY Mt Sinai Sch of Med	2,870	6.2
				Washington State Univ	2,613	5.4
3.0-4.9%	Case Western Reserve U	3,433	4.8	Univ of Cal-Santa Barbara	1,970	4.6
	Iowa St U of Sci & Tech	3,597	4.6	University of Oklahoma	2,026	4.5
	University of Cincinnati	2,299	4.3	Univ of Cal Riverside	1,955	3.8
	Boston University	2,276	3.9	Kans St U-Ag & App Sci	1,515	3.7
	Univ of Nebraska-Lincoln	1,938	3.5	Utah State University	1,316	3.2
	University of Utah	2,268	3.3			

(continued)

Appendix table 5-7. (Continued)

Industrial share[1]	Campus	Thousands of industry dollars	Industrial share	Campus	Thousands of industry dollars	Industrial share
	Rank 51-75 ($78–$53 million)[2]			Rank 76-100 ($52–$36 million)[2]		
	Average industrial share[3]		5.6	Average industrial share[3]		7.3
<3.0%	Univ of Illinois Chicago	1,728	2.7	Tufts University[5]	914	2.0
	SUNY at Stony Brook	1,269	2.3	Woods Hole Ocngrphic Inst	667	1.4
	Colorado State Univ	1,178	2.2	Florida State University	280	0.6
	SUNY at Buffalo	779	1.1			
	Univ of Hawaii-Manoa	261	0.5			
Unknown[6]	Yeshiva University	0	0.0			
	U Tx System Cancer Ctr	0	0.0			
	Rank 100-125 ($35.2-$24.1 million)[2]			Rank 126-150 ($23.7-$16.3 million)[2]		
	Average industrial share[3]		9.4	Average industrial share[3]		7.6
≥10%	Rensselaer Polytech Inst	8,006	31.8	Thomas Jefferson Univ	6,287	30.9
	Lehigh University	6,731	27.0	N Mex Inst Mining & Tech	5,418	22.9
	Texas Tech University	4,123	14.8	Univ of Tenn, Memphis	4,257	20.3
	Syracuse University	3,975	13.1	Univ of Maine Orono	2,051	12.1
	U Tex Hlth Sci Ctr S Anto	4,404	12.8	Montana State Univ[4]	2,383	10.3
	University of Delaware	3,659	11.5	Wake Forest University[5]	2,402	10.2
	University of Dayton	3,335	11.1			
	University of Idaho	2,630	10.9			
5.0-9.9%	U TX Hlth Sci Ctr Houston	3,494	9.9	University of N Dakota	1,583	9.7
	Univ of Vt & St Agric Col	2,877	9.1	Rush University	1,320	8.1
	Univ of Ark Fayetteville	2,353	8.6	San Diego State Univ	1,353	8.0
	U of Houston	1,959	8.0	Med Univ of So Carolina	1,548	7.9
	Medical College of Wis	2,018	6.7	Rice University[4]	1,327	7.6
	Univ of South Carolina	1,531	5.2	University of Wyoming	1,216	7.0
				Howard University	1,112	6.7
				Southern Ill U-Carbondale	1,191	6.4
				Univ of New Hampshire	1,057	5.4
				SUNY Hlth Sci Ctr-Brklyn	897	5.3
3.0-4.9%	Univ of Med & Dent of NJ	1,421	4.4			
	U Tex Med Brnch Galveston	1,146	4.4			
	Univ of Rhode Island	1,130	4.1			
	Univ of Alaska Fairbanks	1,217	4.0			
	Dartmouth College[5]	1,024	3.6			
	West Virginia University	862	3.4			
<3.0%	George Washington Univ*	359	1.5	North Dakota St. Univ[5]	551	2.4
	Oregon Hlth Sciences Univ	243	0.9	Univ of Cal Santa Cruz	460	2.1
				University of Louisville	403	1.8
				Brandeis University	401	1.8
				SUNY Hlth Sci Ctr–Syracuse	354	1.7
				SUNY at Albany	271	1.4
				Univ of Oregon Main	101	0.6
				St John's Univ (NY)[4]	36	0.2
				Univ of California	19	0.1
Unknown[6]	Temple Univ	0	0.0			
	Univ of P R-Mayagueq	0	0.0			
	Univ of P R-Med Sci Cmpus	0	0.0			

(continued)

Appendix table 5-7. (Continued)

Industrial share[1]	Campus	Thousands of industry dollars	Industrial share	Campus	Thousands of industry dollars	Industrial share
	Rank 151-175 ($15.8-$10.1 million)[2]			Rank 176-200 ($10.1-$6.9 million)[2]		
	Average industrial share[3] ..		9.9	Average industrial share[3] ...		11.5
≥10%	Desert Research Institute ..	3,378	26.2	University of Akron	2,575	35.8
	Michigan Tech University ..	2,740	21.6	Oregon Graduate Center ...	1,722	24.9
	University of Notre Dame ..	2,824	19.6	Univ of Central Florida[4]	2,158	24.9
	Brigham Young University .	2,150	19.0	Colorado School of Mines ..	1,995	23.4
	Drexel University	2,468	15.6	Stevens Instit. of Tech[5]	1,852	20.8
	Albany Medical College ...	1,661	12.5	CUNY City College	1,397	15.4
	University of Alabama	1,354	10.1	Clarkson University	1,113	15.0
				University of Lowell	1,201	14.4
				Univ of South Alabama	914	11.9
				Illinois Inst of Tech	1,002	11.8
				Medical Col of Georgia	1,011	10.1
5.0-9.9%	SUNY Col of Env Sci & For	1,153	9.9	SUNY at Binghamton	836	9.8
	NJ Inst of Technology	1,026	9.8	Cleveland State Univ	484	7.0
	Univ Alabama Huntsville ...	992	8.9	U of Arkansas Med Sci Cam	476	5.9
	University of Denver	1,027	8.4	Loyola Univ–Chicago	407	5.7
	Univ of Missouri Rolla	1,153	7.8	Loma Linda University	420	5.6
	New York Medical College .	800	6.8	Polytechnic University	465	5.5
	Univ of Texas at Dallas	658	6.2	Tenn Technological Univ ...	371	5.3
	University of Mississippi ...	766	5.7			
	Northeastern University ...	561	5.5			
3.0-4.9%	U of Neb Med Ctr at Omaha	583	4.7	Univ of Missouri Sys Off ...	438	4.6
	Univ of Nevada–Reno	687	4.5	South Dakota State Univ ...	340	4.1
	Univ of Wis-Milwaukee	407	3.7			
3.0%	Univ of South Florida	117	0.9	Wright State University[5]	65	0.9
	U of MD Center for EES ...	21	0.2	Ohio University	62	0.7
				Hahnemann University	33	0.4
Unknown[6]	US Naval Postgrad School .	0	0.0	Florida A&M Univ	0	0.0
	Unif Serv Univ of Hlth Sc ..	0	0.0	Med Col of Ohio at Toledo ..	0	0.0
	Medical Col of Penn	0	0.0			
	St. Louis Univ	0	0.0			

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[1] Percentage of total R&D provided by industry.

[2] Ranking is derived by sorting campuses receiving R&D funding into groups of 25 from highest to lowest funding. Dollars show range of total R&D expenditures per campus, for the 25 campuses.

[3] Data include only those campuses reporting that they received separate industrial R&D support.

[4] Data for industrial support were imputed.

[5] Data for industrial support were estimated.

[6] Includes campuses reporting no industrial support and campuses reporting industrial support data not available.

SOURCE: NSF, Academic Science/Engineering: R&D Funds, Fiscal Year 1987, NSF 89-311 (Washington, DC: NSF 1989).

See text table 5-2.

Science & Engineering Indicators—1989

Appendix table 5-8. Federal and non-Federal R&D expenditures at universities and colleges, by field and source of funds: 1987

Field	Total		Federal		Non-Federal[1]	
	Thousands of dollars	Percent	Thousands of dollars	Percent	Thousands of dollars	Percent
Total	12,081,531	100.0	7,325,710	60.6	4,755,822	39.4
Total sciences	10,192,813	84.4	6,213,969	61.0	3,978,844	39.0
Physical sciences	1,378,741	11.4	1,040,635	75.5	338,106	24.5
Astronomy	109,921	0.9	72,355	65.8	37,566	34.2
Chemistry	507,788	4.2	365,480	72.0	142,308	28.0
Physics	657,587	5.4	526,111	80.0	131,477	20.0
Other physical sciences	103,444	0.9	76,690	74.1	26,755	25.9
Environmental sciences	832,003	6.9	546,008	65.6	285,994	34.4
Atmospheric	132,008	1.1	107,396	81.4	24,612	18.6
Earth sciences	285,552	2.4	161,344	56.5	124,208	43.5
Oceanography	296,247	2.5	218,816	73.9	77,431	26.1
Other environmental sciences	118,196	1.0	58,453	49.5	59,744	50.5
Mathematical sciences	180,491	1.5	131,271	72.7	49,220	27.3
Computer science	370,284	3.1	252,680	68.2	117,604	31.8
Life sciences	6,478,485	53.6	3,826,175	59.1	2,652,310	40.9
Agricultural sciences	1,169,304	9.7	299,467	25.6	869,837	74.4
Biological sciences	2,057,203	17.0	1,397,686	67.9	659,517	32.1
Medical sciences	3,011,773	24.9	1,992,550	66.2	1,019,223	33.8
Other life sciences	240,205	2.0	136,472	56.8	103,733	43.2
Psychology	187,637	1.6	122,141	65.1	65,496	34.9
Social sciences	496,833	4.1	168,607	33.9	328,226	66.1
Economics	144,132	1.2	42,624	29.6	101,508	70.4
Political science	80,989	0.7	23,721	29.3	57,268	70.7
Sociology	88,040	0.7	43,092	48.9	44,948	51.1
Other social sciences	183,672	1.5	59,169	32.2	124,503	67.8
Other sciences	268,339	2.2	126,451	47.1	141,888	52.9
Total engineering	1,888,718	15.6	1,111,740	58.9	776,978	41.1
Aeronautical and astronautical	116,266	1.0	87,669	75.4	28,598	24.6
Chemical	140,438	1.2	69,880	49.8	70,558	50.2
Civil	190,975	1.6	92,361	48.4	98,614	51.6
Electrical	445,927	3.7	292,735	65.6	153,192	34.4
Mechanical	274,609	2.3	175,915	64.1	98,694	35.9
Other engineering	720,502	6.0	393,181	54.6	324,322	45.0

[1] See appendix table 5-2 for detail on non-Federal sources.

SOURCE: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989).

Appendix table 5-9. Expenditures for academic R&D, by field: 1976-87

Field	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of current dollars											
Total	3,729,007	4,066,953	4,624,673	5,361,408	6,061,578	6,845,162	7,324,391	7,883,642	8,623,264	9,694,563	10,925,507	12,081,531
Total sciences	3,297,280	3,568,480	4,023,611	4,593,001	5,195,716	5,877,110	6,291,150	6,761,253	7,399,957	8,275,072	9,283,706	10,192,813
Physical sciences	379,379	423,457	496,399	601,904	678,083	766,730	824,472	900,889	995,548	1,147,737	1,281,940	1,378,741
Astronomy	26,294	32,361	36,782	48,459	58,592	67,303	73,160	73,493	80,118	95,115	100,189	109,921
Chemistry	140,142	159,353	183,131	206,421	244,823	285,505	308,667	335,890	369,945	422,087	468,386	507,788
Physics	183,050	201,655	235,099	292,033	322,473	357,343	366,964	416,946	471,198	550,333	628,395	657,587
Other	29,893	30,088	41,387	54,991	52,195	56,579	75,681	74,560	74,288	80,202	84,970	103,444
Environmental sciences	288,531	319,398	379,391	452,915	508,551	550,360	558,621	617,940	651,074	708,834	780,147	832,003
Atmospheric	NA	NA	NA	NA	67,386	79,166	86,365	97,992	104,792	110,202	123,731	132,008
Earth sciences	NA	NA	NA	NA	187,867	190,158	195,719	217,438	227,585	252,669	275,167	285,552
Oceanography	NA	NA	NA	NA	171,669	187,875	198,383	223,885	238,730	256,594	277,918	296,247
Other	NA	NA	NA	NA	81,629	93,161	78,154	78,625	79,967	89,369	103,331	118,196
Mathematical sciences	42,491	52,312	58,756	78,477	78,773	88,532	97,985	107,999	124,801	129,898	153,452	180,491
Computer science	44,503	55,563	67,422	97,921	113,655	132,797	149,347	175,658	223,577	281,142	318,465	370,284
Life sciences	2,101,695	2,258,806	2,538,004	2,832,523	3,217,642	3,694,867	4,015,390	4,307,626	4,715,507	5,277,846	5,894,747	6,478,485
Agricultural sciences	412,867	460,647	521,745	602,485	678,816	788,014	864,336	921,103	955,481	1,054,843	1,144,474	1,169,304
Biological sciences	710,724	772,290	808,500	914,806	1,030,191	1,188,664	1,288,261	1,420,410	1,572,032	1,721,128	1,869,375	2,057,203
Medical sciences	897,376	950,907	1,128,652	1,237,556	1,416,364	1,605,247	1,738,706	1,834,164	2,037,191	2,322,316	2,658,020	3,011,773
Other life sciences	80,728	74,962	79,107	77,676	92,271	112,942	124,087	131,949	150,803	179,558	222,877	240,205
Psychology	77,888	85,133	89,664	100,531	111,084	128,738	132,272	136,850	144,712	157,652	169,543	187,637
Social sciences	262,261	268,087	277,497	295,138	341,725	370,518	357,257	348,992	366,457	386,937	458,299	496,833
Economics	65,447	72,124	79,129	83,089	90,817	99,751	96,161	99,086	109,867	118,121	132,855	144,132
Political science	28,355	32,314	36,571	45,431	55,391	56,485	61,561	56,009	57,053	59,745	69,060	80,989
Sociology	66,246	61,939	66,900	74,641	87,992	94,414	79,821	78,440	74,030	77,633	87,857	88,040
Other social sciences	102,213	101,710	94,897	91,977	107,525	119,868	119,714	115,457	125,507	131,439	168,527	183,672
Other sciences	100,532	105,724	116,478	133,592	146,203	144,568	155,806	165,299	178,281	185,026	227,114	268,339
Total engineering	431,727	498,473	601,062	768,407	865,862	968,052	1,033,241	1,122,389	1,223,307	1,419,491	1,641,802	1,888,718
Aeronautical/astronautical	NA	NA	NA	NA	45,983	45,888	60,255	65,739	67,061	86,498	99,872	116,266
Chemical	NA	NA	NA	NA	67,768	84,399	83,173	90,764	95,360	109,263	125,521	140,438
Civil	NA	NA	NA	NA	88,132	114,122	114,543	124,882	140,912	155,274	178,697	190,975
Electrical	NA	NA	NA	NA	184,286	192,848	224,245	261,241	294,850	337,607	396,218	445,927
Mechanical	NA	NA	NA	NA	147,157	149,096	142,352	148,556	178,646	507,414	226,709	274,609
Other engineering	NA	NA	NA	NA	332,536	381,699	408,673	431,207	446,478	523,435	614,784	720,502

(continued)

Appendix table 5-9. (Continued)

Field	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of constant 1982 dollars[1]											
Total	5,912,489	6,067,362	6,448,233	6,882,424	7,153,148	7,343,806	7,324,391	7,563,698	7,970,482	8,692,337	9,535,265	10,217,804
Total sciences	5,227,969	5,323,706	5,610,166	5,896,022	6,131,362	6,305,235	6,291,150	6,486,859	6,839,779	7,419,593	8,102,379	8,620,444
Physical sciences	601,521	631,743	692,135	772,662	800,192	822,583	824,472	864,328	920,185	1,029,084	1,118,817	1,166,053
Astronomy	41,690	48,278	51,286	62,207	69,143	72,206	73,160	70,510	74,053	85,282	87,440	92,964
Chemistry	222,201	237,734	255,342	264,982	288,911	306,303	308,667	322,258	341,940	378,452	408,785	429,455
Physics	290,233	300,843	327,801	374,882	380,544	383,374	366,964	400,025	435,528	493,439	548,433	556,146
Other	47,397	44,887	57,706	70,592	61,594	60,701	75,681	71,534	68,664	71,911	74,158	87,486
Environmental sciences	457,477	476,500	528,989	581,406	600,131	590,452	558,621	592,862	601,788	635,555	680,875	703,656
Atmospheric	NA	NA	NA	NA	79,521	84,933	86,365	94,015	96,859	98,809	107,987	111,644
Earth sciences	NA	NA	NA	NA	221,698	204,010	195,719	208,614	210,357	226,548	240,153	241,502
Oceanography	NA	NA	NA	NA	202,583	201,561	198,383	214,799	220,658	230,067	242,554	250,547
Other	NA	NA	NA	NA	96,329	99,947	78,154	75,434	73,913	80,130	90,182	99,963
Mathematical sciences	67,371	78,043	81,924	100,741	92,958	94,981	97,985	103,616	115,354	116,469	133,926	152,648
Computer science	70,561	82,893	94,007	125,701	134,122	142,471	149,347	168,529	206,652	252,077	277,941	313,163
Life sciences	3,332,321	3,369,843	3,538,767	3,636,101	3,797,076	3,964,024	4,015,390	4,132,808	4,358,542	4,732,221	5,144,656	5,479,098
Agricultural sciences	654,617	687,225	727,475	773,408	801,057	845,418	864,336	883,722	883,151	945,793	998,843	988,924
Biological sciences	1,126,881	1,152,156	1,127,301	1,174,334	1,215,708	1,275,254	1,288,261	1,362,765	1,453,029	1,543,197	1,631,502	1,739,854
Medical sciences	1,422,825	1,418,629	1,573,692	1,588,647	1,671,423	1,722,183	1,738,706	1,759,728	1,882,975	2,082,234	2,319,794	2,547,169
Other life sciences	127,997	111,834	110,300	99,712	108,887	121,169	124,087	126,594	139,387	160,995	194,516	203,150
Psychology	123,495	127,007	125,020	129,051	131,088	138,116	132,272	131,296	133,757	141,354	147,969	158,692
Social sciences	415,825	399,951	386,917	378,868	403,263	397,509	357,257	334,829	338,716	346,935	399,982	420,190
Economics	103,769	107,600	110,330	106,661	107,171	107,017	96,161	95,065	101,550	105,910	115,950	121,898
Political science	44,958	48,208	50,991	58,320	65,366	60,600	61,561	53,736	52,734	53,569	60,272	68,495
Sociology	105,036	92,405	93,279	95,816	103,838	101,292	79,821	75,257	68,426	69,607	76,677	74,459
Other social sciences	162,063	151,738	132,316	118,071	126,888	128,600	119,714	110,771	116,006	117,851	147,082	155,338
Other sciences	159,397	157,726	162,407	171,492	172,531	155,099	155,806	158,591	164,785	165,898	198,214	226,944
Total engineering	684,520	743,657	838,067	986,402	1,021,787	1,038,571	1,033,241	1,076,839	1,130,702	1,272,744	1,432,887	1,597,360
Aeronautical/astronautical	NA	NA	NA	NA	54,264	49,231	60,255	63,071	61,984	77,556	87,164	98,331
Chemical	NA	NA	NA	NA	79,972	90,547	83,173	87,080	88,141	97,967	109,549	118,774
Civil	NA	NA	NA	NA	104,003	122,435	114,543	119,814	130,245	139,222	155,958	161,515
Electrical	NA	NA	NA	NA	217,472	206,896	224,245	250,639	272,530	302,705	345,800	377,137
Mechanical	NA	NA	NA	NA	173,657	159,957	142,352	142,527	165,122	454,957	197,861	232,247
Other engineering	NA	NA	NA	NA	392,419	409,504	408,673	413,707	412,680	469,322	536,554	609,356

NA = Not available.

[1] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989), and the same publication title for earlier years.

See figure O-21 in Overview.

Appendix table 5-10. Capital fund expenditures for facilities and certain equipment in academic S/E: 1964-87

	Total		Federal sources		Non-Federal sources	
	Current dollars	Constant 1982 dollars[1]	Current dollars	Constant 1982 dollars[1]	Current dollars	Constant 1982 dollars[1]
	Thousands of dollars					
1964	529,492	1,602,094	134,439	406,775	395,053	1,195,319
1965	NA	NA	NA	NA	NA	NA
1966	666,997	1,919,968	212,397	611,390	454,600	1,308,578
1967	NA	NA	NA	NA	NA	NA
1968	1,070,727	2,879,072	340,447	915,426	730,280	1,963,646
1969	NA	NA	NA	NA	NA	NA
1970	951,873	2,294,776	279,316	673,375	672,557	1,621,401
1971	NA	NA	NA	NA	NA	NA
1972	912,487	1,981,083	236,836	514,190	675,651	1,466,893
1973	835,862	1,728,774	224,651	464,635	611,211	1,264,139
1974	841,560	1,613,420	225,681	432,671	615,879	1,180,750
1975	1,018,773	1,771,163	270,083	469,546	748,690	1,301,617
1976	1,043,153	1,680,337	206,890	333,264	836,263	1,347,073
1977	960,014	1,432,215	195,519	291,689	764,495	1,140,527
1978	NA	NA	NA	NA	NA	NA
1979	696,218	893,733	164,460	211,117	531,758	682,616
1980	794,512	937,588	149,563	176,496	644,949	761,092
1981	958,588	1,028,418	153,800	165,004	804,788	863,414
1982	969,147	969,147	116,651	116,651	852,496	852,496
1983	1,096,594	1,052,091	129,294	124,047	967,300	928,044
1984	1,211,821	1,120,086	138,383	127,907	1,073,438	992,179
1985	1,249,941	1,120,722	103,758	93,031	1,146,183	1,027,690
1986	1,516,807	1,323,797	148,647	129,732	1,368,160	1,194,065
1987	1,779,796	1,505,240	167,478	141,642	1,612,319	1,363,599

NA = Not available.

[1] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: Data are for expenditures on facilities used for research, development, and instruction, and for expenditures on nonfixed equipment costing over $1 million.

SOURCES: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989); and the same publication title for earlier years.

See figure 5-3.

Science & Engineering Indicators—1989

Appendix table 5-11. Capital expenditures at universities and colleges, by field and source of funds: 1980-87

Field	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of current dollars							
Total	794,512	958,588	969,147	1,096,594	1,211,821	1,249,941	1,516,807	1,779,796
Engineering	89,297	103,329	144,457	134,539	141,969	182,386	309,938	389,188
Total sciences	705,215	855,259	824,690	962,055	1,069,852	1,067,555	1,206,869	1,390,609
Physical sciences	77,154	87,813	82,100	96,752	114,698	119,551	142,396	156,052
Environmental sciences	36,208	35,025	42,365	40,965	36,662	53,822	46,793	51,526
Mathematical/computer sciences	32,318	30,517	34,328	52,897	49,563	76,772	89,579	81,422
Life sciences	459,057	603,551	590,353	678,378	740,785	712,304	797,493	944,562
Psychology	17,982	10,991	12,798	16,667	35,190	13,909	18,765	10,703
Social sciences	35,073	45,138	30,797	40,718	51,933	61,785	50,390	55,381
Other sciences, N.E.C.	47,423	42,224	31,949	35,678	41,022	29,413	61,453	90,964
Federal sources	149,563	153,800	116,651	129,294	138,383	103,758	148,647	167,478
Engineering	20,438	17,601	18,136	15,831	23,267	12,623	29,558	39,101
Total sciences	129,125	136,199	98,515	113,463	115,116	91,136	119,089	128,377
Physical sciences	22,463	25,529	20,154	17,952	17,619	30,489	34,059	35,171
Environmental sciences	8,033	6,866	4,404	3,488	3,269	3,075	5,642	12,010
Mathematical/computer sciences	5,653	4,944	3,798	4,276	4,821	6,657	13,892	9,399
Life sciences	86,105	89,410	66,004	80,565	84,855	46,281	55,654	54,661
Psychology	2,002	1,580	1,023	1,004	981	761	1,346	796
Social sciences	1,528	6,376	1,374	4,845	2,924	2,099	2,430	3,431
Other sciences, N.E.C.	3,341	1,494	1,758	1,333	646	1,774	6,065	12,909
Non-Federal sources	644,949	804,788	852,496	967,300	1,073,438	1,146,183	1,368,160	1,612,319
Engineering	68,859	85,728	126,321	118,708	118,702	169,763	280,380	350,087
Total sciences	576,090	719,060	726,175	848,592	954,736	976,419	1,087,780	1,262,232
Physical sciences	54,691	62,284	61,946	78,800	97,078	89,062	108,337	120,881
Environmental sciences	28,175	28,159	37,961	37,477	33,393	50,747	41,151	39,516
Mathematical/computer sciences	26,665	25,573	30,530	48,621	44,742	70,115	75,687	72,023
Life sciences	372,952	514,141	524,349	597,813	655,930	666,023	741,839	889,901
Psychology	15,980	9,411	11,775	15,663	34,209	13,148	17,419	9,906
Social sciences	33,545	38,762	29,423	35,873	49,009	59,686	47,960	51,950
Other sciences, N.E.C.	44,082	40,730	30,191	34,345	40,376	27,639	55,388	78,055
	Thousands of constant 1982 dollars[1]							
Total	937,588	1,028,418	969,147	1,052,091	1,120,086	1,120,722	1,323,797	1,505,240
Engineering	105,378	110,856	144,457	129,079	131,222	163,531	270,499	329,151
Total sciences	832,210	917,561	824,690	923,012	988,864	957,191	1,053,298	1,176,090
Physical sciences	91,048	94,210	82,100	92,825	106,015	107,192	124,276	131,979
Environmental sciences	42,728	37,576	42,365	39,303	33,887	48,258	40,839	43,577
Mathematical/computer sciences	38,138	32,740	34,328	50,750	45,811	68,835	78,180	68,862
Life sciences	541,724	647,517	590,353	650,847	684,707	638,666	696,014	798,851
Psychology	21,220	11,792	12,798	15,991	32,526	12,471	16,377	9,052
Social sciences	41,389	48,426	30,797	39,066	48,002	55,398	43,978	46,838
Other sciences, N.E.C.	55,963	45,300	31,949	34,230	37,917	26,372	53,633	76,932
Federal sources	176,496	165,004	116,651	124,047	127,907	93,031	129,732	141,642
Engineering	24,118	18,883	18,136	15,189	21,506	11,318	25,797	33,069
Total sciences	152,378	146,121	98,515	108,858	106,402	81,714	103,935	108,573
Physical sciences	26,508	27,389	20,154	17,223	16,285	27,337	29,725	29,745
Environmental sciences	9,480	7,366	4,404	3,346	3,022	2,757	4,924	10,157
Mathematical/computer sciences	6,671	5,304	3,798	4,102	4,456	5,969	12,124	7,949
Life sciences	101,611	95,923	66,004	77,295	78,431	41,496	48,572	46,229
Psychology	2,363	1,695	1,023	963	907	682	1,175	673
Social sciences	1,803	6,840	1,374	4,648	2,703	1,882	2,121	2,902
Other sciences, N.E.C.	3,943	1,603	1,758	1,279	597	1,591	5,293	10,918

(continued)

Appendix table 5-11. (Continued)

Field	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of constant 1982 dollars[1]							
Non-Federal sources	761,092	863,414	852,496	928,044	992,179	1,027,690	1,194,065	1,363,599
Engineering	81,259	91,973	126,321	113,890	109,716	152,213	244,702	296,082
Total sciences	679,832	771,441	726,175	814,153	882,462	875,477	949,363	1,067,517
Physical sciences	64,540	66,821	61,946	75,602	89,729	79,855	94,551	102,234
Environmental sciences	33,249	30,210	37,961	35,956	30,865	45,501	35,915	33,420
Mathematical/computer sciences	31,467	27,436	30,530	46,648	41,355	62,866	66,056	60,913
Life sciences	440,113	551,594	524,349	573,552	606,276	597,169	647,442	752,623
Psychology	18,858	10,097	11,775	15,027	31,619	11,789	15,202	8,378
Social sciences	39,586	41,586	29,423	34,417	45,299	53,516	41,857	43,936
Other sciences, N.E.C.	52,020	43,697	30,191	32,951	37,320	24,782	48,340	66,014

N.E.C. = Not elsewhere classified.

[1] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989).

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Appendix table 5-12. Cost and square footage of academic R&D construction: 1986+1987 and 1988+1989

Field	New R&D space		Cost[1]		Cost per square foot	
	1986+1987	1988+1989	1986+1987	1988+1989	1986+1987	1988+1989
	Thousands of square feet		Millions of dollars		Dollars	
Total	9,989	11,829	2,063	3,399	207	287
Engineering	2,409	1,903	434	501	180	263
Physical sciences	803	1,782	183	533	228	299
Environmental sciences	384	427	57	126	148	295
Mathematics	9	34	2	6	222	176
Computer science	240	224	61	69	254	308
Agricultural sciences	1,542	809	153	216	99	267
Biological sciences	1,730	2,435	478	668	276	274
Medical sciences	1,927	3,263	502	1083	261	332
Psychology	134	78	24	29	179	372
Social sciences	203	233	38	62	187	266
Other sciences	607	641	140	105	231	164

[1] Project cost estimates are prorated to reflect R&D component only.

Note: Data for 2 years are combined, e.g. 1986+1987 means data for 1986 and 1987 are added together.

SOURCE: NSF, *Scientific and Engineering Research Facilities at Universities and Colleges: 1988*, NSF 88-320 (Washington, DC: NSF, 1988).

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Appendix table 5-13. Current fund expenditures for research equipment at universities and colleges, by field: 1980-87

Field	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of current dollars							
Federal and non-Federal								
Total	333,468	413,972	408,479	435,178	518,125	654,840	778,346	832,518
Engineering	55,620	69,008	65,861	75,018	90,650	119,458	142,161	172,044
Physical sciences	54,019	76,141	78,126	79,375	107,450	141,532	162,989	164,487
Environmental sciences	24,458	31,479	28,321	31,521	40,806	46,992	52,456	56,100
Mathematics	1,605	1,902	2,556	2,668	4,539	5,747	5,365	8,193
Computer science	8,153	10,899	12,672	15,615	19,056	38,668	46,088	48,581
Life sciences	170,007	202,184	199,574	205,680	225,575	269,603	327,553	333,615
Psychology	4,291	6,022	5,784	6,629	7,066	8,480	8,329	10,417
Social sciences	8,989	9,179	7,143	8,961	12,727	9,334	13,552	11,927
Other sciences	6,326	7,158	8,461	9,711	10,257	15,026	19,852	27,154
Federal								
Total	220,061	265,048	266,780	272,819	335,495	427,159	502,176	524,733
Engineering	34,984	42,396	43,220	48,958	59,278	75,960	82,103	99,086
Physical sciences	44,364	58,475	62,642	62,055	86,746	113,097	131,492	129,676
Environmental sciences	16,212	19,165	18,423	19,649	29,477	32,102	36,840	36,699
Mathematics	1,111	1,127	1,617	1,476	3,213	4,700	3,813	6,045
Computer science	3,446	5,436	8,215	10,229	14,056	32,709	38,881	39,555
Life sciences	109,112	126,175	120,189	117,039	128,837	151,265	187,242	187,884
Psychology	3,278	4,466	4,219	4,749	5,016	6,198	5,668	7,929
Social sciences	4,292	3,999	2,907	2,917	3,484	4,196	4,503	3,730
Other sciences	3,262	3,809	5,306	5,747	5,387	6,932	11,635	14,127
Non-Federal								
Total	113,407	148,924	141,699	162,359	182,632	227,682	276,169	307,785
Engineering	20,636	26,612	22,641	26,060	31,372	43,498	60,058	72,958
Physical sciences	9,655	17,666	15,484	17,320	20,705	28,435	31,497	34,810
Environmental sciences	8,246	12,314	9,898	11,872	11,329	14,891	15,616	19,400
Mathematics	494	775	939	1,192	1,326	1,047	1,553	2,148
Computer science	4,707	5,463	4,457	5,386	4,999	5,959	7,208	9,026
Life sciences	60,895	76,009	79,385	88,641	96,737	118,338	140,310	145,731
Psychology	1,013	1,556	1,565	1,880	2,050	2,282	2,660	2,488
Social sciences	4,697	5,180	4,236	6,044	9,243	5,138	9,049	8,197
Other sciences	3,064	3,349	3,155	3,964	4,870	8,094	8,217	13,027
	Thousands of constant 1982 dollars[1]							
Federal and non-Federal								
Total	393,519	444,128	408,479	417,517	478,903	587,142	679,304	704,092
Engineering	65,636	74,035	65,861	71,974	83,788	107,108	124,071	145,504
Physical sciences	63,747	81,688	78,126	76,154	99,316	126,900	142,249	139,113
Environmental sciences	28,862	33,772	28,321	30,242	37,717	42,134	45,781	47,446
Mathematics	1,894	2,041	2,556	2,560	4,195	5,153	4,682	6,929
Computer science	9,621	11,693	12,672	14,981	17,613	34,670	40,223	41,087
Life sciences	200,622	216,912	199,574	197,333	208,499	241,731	285,873	282,151
Psychology	5,064	6,461	5,784	6,360	6,531	7,603	7,269	8,810
Social sciences	10,608	9,848	7,143	8,597	11,764	8,369	11,828	10,087
Other sciences	7,465	7,679	8,461	9,317	9,481	13,473	17,326	22,965

(continued)

Appendix table 5-13. (Continued)

Field	1980	1981	1982	1983	1984	1985	1986	1987
	Thousands of constant 1982 dollars[1]							
Federal								
Total	259,690	284,356	266,780	261,747	310,098	382,999	438,275	443,786
Engineering	41,284	45,484	43,220	46,971	54,791	68,107	71,656	83,801
Physical sciences	52,353	62,735	62,642	59,537	80,179	101,405	114,760	109,672
Environmental sciences	19,131	20,561	18,423	18,852	27,246	28,783	32,152	31,038
Mathematics	1,311	1,209	1,617	1,416	2,970	4,214	3,328	5,112
Computer science	4,067	5,832	8,215	9,814	12,992	29,328	33,933	33,453
Life sciences	128,761	135,366	120,189	112,289	119,084	135,627	163,416	158,901
Psychology	3,868	4,791	4,219	4,556	4,636	5,557	4,947	6,706
Social sciences	5,065	4,290	2,907	2,799	3,220	3,762	3,930	3,155
Other sciences	3,849	4,086	5,306	5,514	4,979	6,215	10,154	11,948
Non-Federal								
Total	133,829	159,773	141,699	155,770	168,807	204,144	241,027	260,305
Engineering	24,352	28,551	22,641	25,002	28,997	39,001	52,416	61,703
Physical sciences	11,394	18,953	15,484	16,617	19,138	25,495	27,489	29,440
Environmental sciences	9,731	13,211	9,898	11,390	10,471	13,352	13,629	16,407
Mathematics	583	831	939	1,144	1,226	939	1,355	1,817
Computer science	5,555	5,861	4,457	5,167	4,621	5,343	6,291	7,634
Life sciences	71,861	81,546	79,385	85,044	89,414	106,104	122,456	123,250
Psychology	1,195	1,669	1,565	1,804	1,895	2,046	2,322	2,104
Social sciences	5,543	5,557	4,236	5,799	8,543	4,607	7,898	6,933
Other sciences	3,616	3,593	3,155	3,803	4,501	7,257	7,171	11,017

[1] See appendix table 4-1 for GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: NSF, *Academic Science/Engineering: R&D Funds, Fiscal Year 1987*, NSF 89-311 (Washington, DC: NSF, 1989).

Science & Engineering Indicators—1989

Appendix table 5-14. National stock of in-use academic instrumentation, in selected fields: 1982/83 and 1985/86

Field	Instrument systems			Aggregate purchase price			Mean price/system		
	1982/83	1985/86		1982/83	1985/86		1982/83	1985/86	
	Number		Percent change	Millions of dollars		Percent change	Thousands of dollars		Percent change
Total	36,300	53,900	48	1311	1882	44	36.1	36.3	1
Engineering	6,800	9,300	37	261	349	34	38.5	39.5	3
Agricultural sciences	1,600	2,600	63	37	60	62	22.7	24.0	6
Biological sciences	15,300	22,300	46	420	624	49	27.4	28.6	4
Colleges & universities	6,400	10,300	61	166	272	64	25.9	27.3	5
Medical schools	8,900	12,000	35	254	352	39	28.6	29.7	4
Computer science	900	2,200	144	50	93	86	57.8	44.8	-22
Environmental sciences	2,100	3,300	57	109	160	47	51.6	50.6	-2
Materials science	600	800	33	34	43	26	53.0	54.8	3
Physical sciences	8,800	12,300	40	390	511	31	44.6	43.9	-2
Interdisciplinary, N.E.C	200	1,200	500	8	42	425	(1)	39.0	(1)

N.E.C. = Not elsewhere classified.

[1] Estimate is unstable.

Note: Estimates for the agricultural, biological, and environmental sciences are for 1983 and 1986. Estimates for all other fields are for 1982 and 1985. Data apply to instrument systems costing between $10,000 and $1 million. Data exclude instrument systems not yet in use (approximately 1,200 systems), and inactive/inoperable systems (approximately 9,300 systems). Detail may not add to total because of rounding. Data are adjusted for inflation both in terms of instrument prices and in weighting school responses based on their total R&D expenditures.

SOURCE: NSF, *Academic Research Equipment in Selected Science/Engineering Fields: 1982-83 to 1985-86*, SRS 88-D1 (Washington, DC: NSF, 1988).

Science & Engineering Indicators—1989

Appendix table 5-15. Instrumentation-related expenditures in academic departments and facilities, in selected fields: 1982/83 and 1985/86

Field	Total			Purchases of research equipment[1]			Purchases of research-related computer services			Equipment maintenance and repair		
	1982/83	1985/86		1982/83	1985/86		1982/83	1985/86		1982/83	1985/86	
	Millions of dollars		Percent change	Millions of dollars		Percent change	Millions of dollars		Percent change	Millions of dollars		Percent change
Total	638	809	27	413	612	48	121	66	-45	104	131	26
Engineering	146	193	32	86	146	70	41	20	-51	19	26	38
Agricultural sciences	41	41	1	28	30	6	7	5	-29	5	6	20
Biological sciences	192	220	14	132	173	31	28	9	-68	32	38	18
Colleges and universities	79	102	29	52	82	58	13	5	-62	14	15	8
Medical schools	113	118	4	81	91	13	15	4	-73	18	23	26
Computer science	29	58	100	20	41	108	4	4	0	6	13	103
Environmental sciences	49	63	29	33	46	38	7	7	0	9	10	8
Materials sciences	12	9	-27	10	8	-17	1	1	0	2	1	-57
Physical sciences	151	196	30	91	147	61	32	18	-44	28	31	10
Interdisciplinary, N.E.C	18	30	69	13	21	58	2	3	50	3	6	131

N.E.C. = Not elsewhere classified.

[1] Data are for research equipment costing $10,000 to $1 million per system.

Notes: Estimates for the agricultural, biological, and environmental sciences are for 1983 and 1986. Estimates for all other fields are for 1982 and 1985. Detail may not add to total because of rounding. Data are adjusted for inflation both in terms of instrument prices and in weighting school responses based on their total R&D expenditures.

SOURCE: NSF, *Academic Research Equipment in Selected Science/Engineering Fields: 1982-83 to 1985-86*, SRS 88-D1 (Washington, DC: NSF, 1988).

Appendix table 5-16. Library prices for periodicals in science and nonscience fields: 1980, 1988, and 1989

	Average price per subscription			Average annual percent change	
	1980	1988	1989	1980-89	1988-89
	Dollars			Percent change	
All science categories					
Mathematics	93	264	277	12.9	4.9
Astronomy	109	226	233	8.8	3.1
Physics	199	370	376	7.3	1.6
Chemistry	231	594	591	11.0	-0.5
Geology	79	182	194	10.5	6.6
Natural history	123	291	308	10.7	5.8
Botany	79	161	173	9.1	7.5
Zoology	69	146	158	9.6	8.2
Physiology	200	414	413	8.4	-0.2
Microbiology	128	340	357	12.1	5.0
Non-science categories					
Law	38	106	113	12.9	6.6
Sociology, general	35	100	107	13.2	7.0
Political science	37	96	105	12.3	9.4
Fine arts	30	64	66	9.2	3.1
History, general	31	68	73	10.0	7.4

Notes: These data are from a data base of The Faxon Company, containing approximately 40,000 domestic titles (1989) and 15,000 foreign titles (1989). The prices should be considered approximate, since they are derived from Faxon's client mix, which consists of many types of libraries. Data show all science categories and a sample of non-science categories.

SOURCE: P.R. Young, 1989. "Periodical Prices 1987-1989 Update." *Serials Librarian*, 17: 11-37.

Science & Engineering Indicators—1989

Appendix table 5-17. Doctoral scientists and engineers in academic R&D, by field: 1977-87

Field	1977			1979			1981			1983			1985			1987		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Number																	
Total scientists and engineers	93,781	84,669	9,112	98,096	87,294	10,802	110,046	96,004	14,042	113,345	97,797	15,548	120,691	102,731	17,960	154,586	130,089	24,497
Total scientists	83,932	74,908	9,024	87,370	76,703	10,667	99,414	85,534	13,880	100,283	84,964	15,319	107,544	89,916	17,628	135,527	111,533	23,994
Physical scientists	17,592	16,718	874	17,305	16,374	931	18,587	17,474	1,113	17,483	16,343	1,140	19,268	18,002	1,266	22,407	20,737	1,670
Chemists	8,969	8,310	659	9,123	8,430	693	9,590	8,717	873	8,613	7,756	857	9,765	8,836	929	11,340	10,153	1,182
Physicists/astronomers	8,623	8,408	215	8,182	7,944	238	8,997	8,757	240	8,870	8,587	283	9,503	9,166	337	11,067	10,594	483
Mathematical scientists	6,840	6,449	391	6,784	6,381	403	6,790	6,276	514	7,154	6,602	552	6,842	6,315	527	9,172	8,433	739
Mathematicians	6,092	5,744	348	5,804	5,464	340	5,819	5,413	406	5,962	5,548	414	5,803	5,366	437	7,689	7,055	634
Statisticians	748	705	43	980	917	63	971	863	108	1,192	1,054	138	1,039	949	90	1,483	1,378	105
Computer/information specialists	1,229	1,164	65	1,254	1,169	85	1,941	1,784	157	2,294	2,100	194	2,599	2,344	255	3,491	3,140	351
Environmental scientists	4,392	4,212	180	4,080	3,864	216	4,852	4,558	294	4,676	4,400	276	5,246	4,870	376	6,348	5,827	521
Earth scientists	3,057	2,953	104	2,797	2,677	120	3,274	3,135	139	2,946	2,804	142	3,423	3,219	204	4,250	3,906	344
Oceanographers	730	692	38	650	583	67	849	739	110	855	766	89	978	849	129	1,159	1,034	125
Atmospheric scientists	605	567	38	633	604	29	729	684	45	875	830	45	845	802	43	939	887	52
Life scientists	31,605	27,351	4,254	34,624	29,220	5,404	39,781	33,039	6,742	40,981	33,398	7,583	43,304	34,380	8,924	51,918	40,875	11,043
Biological scientists	21,853	18,366	3,487	23,405	19,242	4,163	26,196	21,220	4,976	27,753	22,084	5,669	29,054	22,404	6,650	34,138	26,629	7,508
Agricultural scientists	4,550	4,453	97	4,445	4,334	111	5,538	5,353	185	5,789	5,537	252	6,184	5,868	316	7,040	6,525	515
Medical scientists	5,202	4,532	670	6,774	5,644	1,130	8,047	6,466	1,581	7,439	5,777	1,662	8,066	6,108	1,958	10,740	7,721	3,019
Psychologists	7,458	6,009	1,449	7,883	6,244	1,639	9,174	6,959	2,215	9,072	6,814	2,258	9,248	6,781	2,467	13,012	9,149	3,863
Social scientists	14,816	13,005	1,811	15,440	13,451	1,989	18,289	15,444	2,845	18,623	15,307	3,316	21,037	17,224	3,813	29,179	23,372	5,807
Economists	4,484	4,217	267	4,783	4,435	348	5,618	5,249	369	6,256	5,724	532	6,428	5,877	551	8,362	7,431	881
Sociologists/anthropologists	3,691	2,986	705	4,033	3,191	842	4,729	3,557	1,172	4,493	3,149	1,344	5,055	3,792	1,263	7,199	5,145	2,054
Other social scientists	6,641	5,802	839	6,624	5,825	799	7,942	6,638	1,304	7,874	6,434	1,440	9,554	7,555	1,999	13,618	1,746	2,872
Engineers	9,849	9,761	88	10,726	10,591	135	10,632	10,470	162	13,062	12,833	229	13,147	12,815	332	19,059	18,556	503
Aeronautical/astronautical	447	437	10	627	621	6	541	538	3	734	726	8	525	511	14	775	762	13
Chemical	790	784	6	682	663	19	932	914	18	1,214	1,188	26	1,139	1,115	24	1,629	1,577	52
Civil	1,209	1,204	5	1,668	1,658	10	1,440	1,413	27	1,930	1,906	24	2,070	2,042	28	2,941	2,878	63
Electrical/electronics	1,927	1,923	4	1,681	1,661	20	2,050	2,025	25	2,287	2,255	32	2,269	2,205	64	3,275	3,198	77
Materials	932	920	12	1,091	1,065	26	1,016	997	19	1,396	1,350	46	1,151	1,117	34	1,582	1,511	71
Mechanical	1,203	1,195	8	1,167	1,162	5	1,186	1,178	8	1,484	1,471	13	1,810	1,786	24	2,797	2,748	49
Nuclear	400	397	3	669	659	10	437	430	7	567	559	8	428	425	3	455	443	6
Systems design	493	479	14	614	602	12	730	708	22	444	425	19	523	492	31	958	021	37
Other	2,448	2,422	26	2,527	2,500	27	2,300	2,267	33	3,006	2,953	53	3,232	3,122	110	4,647	4,512	135

(continued)

Appendix table 5-17. (Continued)

Field	1977			1979			1981			1983			1985			1987		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Percent[1]																	
Total scientists and engineers	100.0	90.3	9.7	100.0	89.0	11.0	100.0	87.2	12.8	100.0	86.3	13.7	100.0	85.1	14.9	100.0	100.0	100.0
Total scientists	89.5	89.2	10.8	89.1	87.8	12.2	90.3	86.0	14.0	88.5	84.7	15.3	89.1	83.6	16.4	87.7	82.3	17.7
Physical scientists	18.8	95.0	5.0	17.6	94.6	5.4	16.9	94.0	6.0	15.4	93.5	6.5	16.0	93.4	6.6	14.5	92.5	7.5
Chemists	9.6	92.7	7.3	9.3	92.4	7.6	8.7	90.9	9.1	7.6	90.0	10.0	8.1	90.5	9.5	7.3	89.5	10.5
Physicists/astronomers	9.2	97.5	2.5	8.3	97.1	2.9	8.2	97.3	2.7	7.8	96.8	3.2	7.9	96.5	3.5	7.2	95.6	4.4
Mathematical scientists	7.3	94.3	5.7	6.9	94.1	5.9	6.2	92.4	7.6	6.3	92.3	7.7	5.7	92.3	7.7	5.9	91.9	8.1
Mathematicians	6.5	94.3	5.7	5.9	94.1	5.9	5.3	93.0	7.0	5.3	93.1	6.9	4.8	92.5	7.5	5.0	91.8	8.2
Statisticians	0.8	94.3	5.7	1.0	93.6	6.4	0.9	88.9	11.1	1.1	88.4	11.6	0.9	91.3	8.7	1.0	92.9	7.1
Computer/information specialists	1.3	94.7	5.3	1.3	93.2	6.8	1.8	91.9	8.1	2.0	91.5	8.5	2.2	90.2	9.8	2.3	89.9	10.1
Environmental scientists	4.7	95.9	4.1	4.2	94.7	5.3	4.4	93.9	6.1	4.1	94.1	5.9	4.3	92.8	7.2	4.1	91.8	8.2
Earth scientists	3.3	96.6	3.4	2.9	95.7	4.3	3.0	95.8	4.2	2.6	95.2	4.8	2.8	94.0	6.0	2.7	91.9	8.1
Oceanographers	0.8	94.8	5.2	0.7	89.7	10.3	0.8	87.0	13.0	0.8	89.6	10.4	0.8	86.8	13.2	0.7	89.2	10.8
Atmospheric scientists	0.6	93.7	6.3	0.6	95.4	4.6	0.7	93.8	6.2	0.8	94.9	5.1	0.7	94.9	5.1	0.6	94.5	5.5
Life scientists	33.7	86.5	13.5	35.3	84.4	15.6	36.1	83.1	16.9	36.2	81.5	18.5	35.9	79.4	20.6	33.6	78.7	21.3
Biological scientists	23.3	84.0	16.0	23.9	82.2	17.8	23.8	81.0	19.0	24.5	79.6	20.4	24.1	77.1	22.9	22.1	78.0	22.0
Agricultural scientists	4.9	97.9	2.1	4.5	97.5	2.5	5.0	96.7	3.3	5.1	95.6	4.4	5.1	94.9	5.1	4.6	92.7	7.3
Medical scientists	5.5	87.1	12.9	6.9	83.3	16.7	7.3	80.4	19.6	6.6	77.7	22.3	6.7	75.7	24.3	6.9	71.9	28.1
Psychologists	8.0	80.6	19.4	8.0	79.2	20.8	8.3	75.9	24.1	8.0	75.1	24.9	7.7	73.3	26.7	8.4	70.3	29.7
Social scientists	15.8	87.8	12.2	15.7	87.1	12.9	16.6	84.4	15.6	16.4	82.2	17.8	17.4	81.9	18.1	18.9	80.1	19.9
Economists	4.8	94.0	6.0	4.9	92.7	7.3	5.1	93.4	6.6	5.5	91.5	8.5	5.3	91.4	8.6	5.4	89.5	10.5
Sociologists/anthropologists	3.9	80.9	19.1	4.1	79.1	20.9	4.3	75.2	24.8	4.0	70.1	29.9	4.2	75.0	25.0	4.7	71.5	28.5
Other social scientists	7.1	87.4	12.6	6.8	87.9	12.1	7.2	83.6	16.4	6.9	81.7	18.3	7.9	79.1	20.9	8.8	78.9	21.1
Engineers	10.5	99.1	0.9	10.9	98.7	1.3	9.7	98.5	1.5	11.5	98.2	1.8	10.9	97.5	2.5	12.3	97.4	2.6
Aeronautical/astronautical	0.5	97.8	2.2	0.6	99.0	1.0	0.5	99.4	0.6	0.6	98.9	1.1	0.4	97.3	2.7	0.5	98.3	1.7
Chemical	0.8	99.2	0.8	0.7	97.2	2.8	0.8	98.1	1.9	1.1	97.9	2.1	0.9	97.9	2.1	1.1	96.8	3.2
Civil	1.3	99.6	0.4	1.7	99.4	0.6	1.3	98.1	1.9	1.7	98.8	1.2	1.7	98.6	1.4	1.9	97.9	2.1
Electrical/electronics	2.1	99.8	0.2	1.7	98.8	1.2	1.9	98.8	1.2	2.0	98.6	1.4	1.9	97.2	2.8	2.1	97.6	2.4
Materials	1.0	98.7	1.3	1.1	97.6	2.4	0.9	98.1	1.9	1.2	96.7	3.3	1.0	97.0	3.0	1.0	95.5	4.5
Mechanical	1.3	99.3	0.7	1.2	99.6	0.4	1.1	99.3	0.7	1.3	99.1	0.9	1.5	98.7	1.3	1.8	98.2	1.8
Nuclear	0.4	99.3	0.8	0.7	98.5	1.5	0.4	98.4	1.6	0.5	98.6	1.4	0.4	99.3	0.7	0.3	98.7	1.3
Systems design	0.5	97.2	2.8	0.6	98.0	2.0	0.7	97.0	3.0	0.4	95.7	4.3	0.4	94.1	5.9	0.6	96.1	3.9
Other	2.6	98.9	1.1	2.6	98.9	1.1	2.1	98.6	1.4	2.7	98.2	1.8	2.7	96.6	3.4	3.0	97.1	2.9

[1] Percentages in "Total" columns are vertical percentages. Percentages in other columns are horizontal percentages.

Note: Data are for doctoral scientists and engineers whose primary or secondary work activity is academic R&D.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1989.

See figures 5-4, 5-5, and 5-6.

Appendix table 5-18. Doctoral scientists and engineers employed in academic R&D, by field, race, ethnic group, and gender: 1977 and 1987

Field	Total employed					White			Black			Asian			Hispanic		
	Total	Male	Female	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Number			Percent		Number			Number			Number			Number		
1977																	
Total scientists and engineers	93,781	84,669	9,112	90.3	9.7	84,319	76,116	8,203	768	637	131	5,952	5,273	679	934	855	79
Total scientists	83,932	74,908	9,024	89.2	10.8	76,035	67,901	8,134	748	617	131	4,843	4,181	662	865	788	77
Physical scientists	17,592	16,718	874	95.0	5.0	15,685	14,959	726	128	111	(1)	1,235	1,109	126	158	156	(1)
Chemists	8,969	8,310	659	92.7	7.3	8,036	7,501	535	74	62	(1)	616	509	107	84	83	(1)
Physicists/astronomers	8,623	8,408	215	97.5	2.5	7,649	7,458	191	54	49	(1)	619	600	(1)	74	73	(1)
Mathematical scientists	6,840	6,449	391	94.3	5.7	6,052	5,699	353	42	38	(1)	461	427	34	61	61	0
Mathematicians	6,092	5,744	348	94.3	5.7	5,383	5,070	313	42	38	(1)	401	370	31	52	52	0
Statisticians	748	705	43	94.3	5.7	669	629	40	0	0	0	60	57	(1)	(1)	(1)	0
Computer/information specialists	1,229	1,164	65	94.7	5.3	1,054	995	59	0	0	0	140	134	(1)	(1)	(1)	0
Environmental scientists	4,392	4,212	180	95.9	4.1	4,079	3,915	164	0	0	0	236	220	(1)	60	55	(1)
Earth scientists	3,057	2,953	104	96.6	3.4	2,856	2,765	91	0	0	0	158	145	(1)	41	41	0
Oceanographers	730	692	38	94.8	5.2	682	647	35	0	0	0	24	21	(1)	(1)	(1)	0
Atmospheric scientists	605	567	38	93.7	6.3	541	503	38	0	0	0	54	54	0	(1)	(1)	(1)
Life scientists	31,605	27,351	4,254	86.5	13.5	28,420	24,681	3,739	306	252	54	2,128	1,718	410	391	358	33
Biological scientists	21,853	18,366	3,487	84.0	16.0	19,626	16,559	3,067	226	178	48	1,448	1,124	324	246	223	23
Agricultural scientists	4,550	4,453	97	97.9	2.1	4,191	4,109	82	33	33	0	244	229	(1)	62	55	(1)
Medical scientists	5,202	4,532	670	87.1	12.9	4,603	4,013	590	47	41	(1)	436	365	71	83	80	(1)
Psychologists	7,458	6,009	1,449	80.6	19.4	7,070	5,709	1,361	140	99	41	76	41	35	37	23	(1)
Social scientists	14,816	13,005	1,811	87.8	12.2	13,675	11,943	1,732	132	117	(1)	567	532	35	156	133	23
Economists	4,484	4,217	267	94.0	6.0	4,064	3,808	256	44	44	0	257	250	(1)	44	40	(1)
Sociologists/anthropologists	3,691	2,986	705	80.9	19.1	3,437	2,769	668	33	(1)	(1)	95	83	(1)	58	43	(1)
Other social scientists	6,641	5,802	839	87.4	12.6	6,174	5,366	808	55	54	(1)	215	199	(1)	54	50	(1)
Engineers	9,849	9,761	88	99.1	0.9	8,284	8,215	69	20	20	0	1,109	1,092	(1)	69	67	(1)
Aeronautical/astronautical	447	437	10	97.8	2.2	388	380	(1)	0	0	0	42	40	(1)	0	0	0
Chemical	790	784	6	99.2	0.8	650	644	(1)	(1)	(1)	0	100	100	0	(1)	(1)	(1)
Civil	1,209	1,204	5	99.6	0.4	980	975	(1)	0	0	0	180	180	0	(1)	(1)	0
Electrical/electronics	1,927	1,923	4	99.8	0.2	1,653	1,650	(1)	(1)	(1)	0	193	192	(1)	0	0	0
Materials	932	920	12	98.7	1.3	740	730	(1)	0	0	0	138	136	(1)	0	0	0
Mechanical	1,203	1,195	8	99.3	0.7	982	980	(1)	0	0	0	209	205	(1)	20	20	0
Nuclear	400	397	3	99.3	0.8	389	387	(1)	0	0	0	(1)	0	(1)	(1)	(1)	(1)
Systems design	493	479	14	97.2	2.8	432	420	(1)	0	0	0	36	34	(1)	(1)	(1)	(1)
Other	2,448	2,422	26	98.9	1.1	2,070	2,049	21	0	0	0	210	205	(1)	(1)	(1)	(1)

(continued)

Appendix table 5-18. (Continued)

Field	Total employed					White			Black			Asian			Hispanic		
	Total	Male	Female	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
	Number			Percent		Number			Number			Number			Number		
1987																	
Total scientists and engineers	154,586	130,089	24,497	84.2	15.8	137,278	115,519	21,759	2,111	1,492	619	13,843	11,868	1,975	2,702	2,247	455
Total scientists	135,527	111,533	23,994	82.3	17.7	121,834	100,493	21,341	1,992	1,381	611	10,462	8,563	1,899	2,317	1,873	444
Physical scientists	22,407	20,737	1,670	92.5	7.5	19,848	18,489	1,359	192	171	(1)	2,179	1,897	282	384	336	48
Chemists	11,340	10,153	1,187	89.5	10.5	10,152	9,189	963	146	127	(1)	986	788	198	199	162	37
Physicists/astronomers	11,067	10,584	483	95.6	4.4	9,696	9,300	396	46	44	(1)	1,193	1,109	84	185	174	(1)
Mathematical scientists	9,172	8,433	739	91.9	8.1	8,069	7,466	603	62	49	(1)	995	877	118	147	128	(1)
Mathematicians	7,689	7,055	634	91.8	8.2	6,889	6,354	535	56	47	(1)	698	613	85	124	107	(1)
Statisticians	1,483	1,378	105	92.9	7.1	1,180	1,112	68	(1)	(1)	(1)	297	264	33	23	21	(1)
Computer/information specialists	3,491	3,140	351	89.9	10.1	3,047	2,729	318	(1)	(1)	(1)	348	316	32	38	28	(1)
Environmental scientists	6,348	5,827	521	91.8	8.2	5,969	5,510	459	30	27	(1)	331	276	55	117	115	(1)
Earth scientists	4,250	3,906	344	91.9	8.1	3,945	3,647	298	24	21	(1)	263	224	39	70	68	(1)
Oceanographers	1,159	1,034	125	89.2	10.8	1,115	1,003	112	(1)	(1)	(1)	42	29	(1)	30	30	0
Atmospheric scientists	939	887	52	94.5	5.5	909	860	49	(1)	(1)	(1)	26	23	(1)	(1)	(1)	0
Life scientists	51,918	40,875	11,043	78.7	21.3	46,364	36,652	9,712	736	521	215	4,456	3,412	1,044	817	649	168
Biological scientists	34,138	26,629	7,509	78.0	22.0	30,595	24,024	6,571	459	348	111	2,857	2,075	782	454	352	102
Agricultural scientists	7,040	6,525	515	92.7	7.3	6,561	6,105	456	97	86	(1)	347	301	46	163	147	(1)
Medical scientists	10,740	7,721	3,019	71.9	28.1	9,208	6,523	2,685	180	87	93	1,252	1,036	216	200	150	50
Psychologists	13,012	9,149	3,863	70.3	29.7	12,295	8,725	3,570	230	92	138	319	182	137	202	129	73
Social scientists	29,179	23,372	5,807	80.1	19.9	26,242	20,922	5,320	736	516	220	1,834	1,603	231	612	488	124
Economists	8,362	7,481	881	89.5	10.5	7,424	6,640	784	107	84	23	739	673	66	220	191	29
Sociologists/anthropologists	7,199	5,145	2,054	71.5	28.5	6,548	4,660	1,888	243	147	96	332	278	54	123	85	38
Other social scientists	13,618	10,746	2,872	78.9	21.1	12,270	9,622	2,648	386	285	101	763	652	111	269	212	57
Engineers	19,059	18,556	503	97.4	2.6	15,444	15,026	418	119	111	(1)	3,381	3,305	76	385	374	(1)
Aeronautical/astronautical	775	762	(1)	98.3	(1)	610	599	(1)	0	0	0	165	163	(1)	(1)	(1)	0
Chemical	1,629	1,577	52	96.8	3.2	1,045	1,005	40	0	0	0	576	564	(1)	64	63	(1)
Civil	2,941	2,878	63	97.9	2.1	2,586	2,534	52	(1)	(1)	(1)	338	329	(1)	58	58	0
Electrical/electronics	3,275	3,198	77	97.6	2.4	2,492	2,432	60	34	31	(1)	725	711	(1)	78	78	0
Materials	1,582	1,511	71	95.5	4.5	1,437	1,379	58	0	0	0	124	112	(1)	60	55	(1)
Mechanical	2,797	2,748	49	98.2	1.8	2,138	2,098	40	(1)	0	(1)	610	602	(1)	(1)	(1)	0
Nuclear	455	449	(1)	98.7	(1)	436	430	(1)	(1)	(1)	0	(1)	(1)	0	(1)	(1)	0
Systems design	958	921	37	96.1	3.9	938	906	32	0	0	0	20	(1)	(1)	0	0	0
Other	4,647	4,512	135	97.1	2.9	3,762	3,643	119	77	75	(1)	808	794	(1)	93	91	(1)

[1] Fewer than 20 individuals.

Notes: Data are for doctoral scientists and engineers with primary or secondary work activity in academic R&D. Hispanics are found in all racial groups, and, therefore, are not separately added into totals.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1989.

See figure 5-7.

Appendix table 5-19. Doctoral scientists and engineers employed in basic research, by field and sector: 1977 and 1987

Field	Total employed	Business/ industry	4-year colleges and univ.	Hospitals and clinics	Nonprofit	Federal Gov't	Other/ no report	Total employed	Business/ industry	4-year colleges and univ.	Hospitals and clinics	Nonprofit	Federal Gov't	Other/ no report
	Number							Percent						
1977														
Total scientists and engineers	88,320	9,014	66,376	1,281	3,194	6,850	1,605	100.0	10.2	75.2	1.5	3.6	7.8	1.8
Total scientists	83,214	7,720	63,148	1,281	3,052	6,428	1,585	94.2	9.3	75.9	1.5	3.7	7.7	1.9
Physical scientists	23,577	5,264	15,045	142	1,025	1,825	276	26.7	22.3	63.8	0.6	4.3	7.7	1.2
Chemists	13,562	3,895	8,130	142	405	839	151	15.4	28.7	59.9	1.0	3.0	6.2	1.1
Physicists/astronomers	10,015	1,369	6,915	(1)	620	986	125	11.3	13.7	69.0	(1)	6.2	9.8	1.2
Mathematical scientists	6,274	184	5,850	(1)	72	94	74	7.1	2.9	93.2	(1)	1.1	1.5	1.2
Mathematicians	5,721	147	5,353	(1)	60	87	74	6.5	2.6	93.6	(1)	1.0	1.5	1.3
Statisticians	553	37	497	(1)	12	7	0	0.6	6.7	89.9	(1)	2.2	1.3	0.0
Computer/information specialists	761	153	538	(1)	25	21	24	0.9	20.1	70.7	(1)	3.3	2.8	3.2
Environmental scientists	4,985	399	3,245	(1)	179	1,025	137	5.6	8.0	65.1	(1)	3.6	20.6	2.7
Earth scientists	3,417	352	2,227	(1)	89	668	81	3.9	10.3	65.2	(1)	2.6	19.5	2.4
Oceanographers	850	2	636	(1)	15	167	30	1.0	0.2	74.8	(1)	1.8	19.6	3.5
Atmospheric scientists	718	45	382	(1)	75	190	26	0.8	6.3	53.2	(1)	10.4	26.5	3.6
Life scientists	31,766	1,382	24,506	937	1,381	2,835	725	36.0	4.4	77.1	2.9	4.3	8.9	2.3
Biological scientists	24,641	861	19,480	678	1,156	1,971	495	27.9	3.5	79.1	2.8	4.7	8.0	2.0
Agricultural scientists	2,299	115	1,439	11	15	642	77	2.6	5.0	62.6	0.5	0.7	27.9	3.3
Medical scientists	4,826	406	3,587	248	210	222	153	5.5	8.4	74.3	5.1	4.4	4.6	3.2
Psychologists	5,755	197	4,982	202	65	145	164	6.5	3.4	86.6	3.5	1.1	2.5	2.8
Social scientists	10,096	141	8,982	(1)	305	483	185	11.4	1.4	89.0	(1)	3.0	4.8	1.8
Economists	2,175	78	1,785	(1)	42	218	52	2.5	3.6	82.1	(1)	1.9	10.0	2.4
Sociologists/anthropologists	3,041	2	2,781	(1)	129	49	80	3.4	0.1	91.5	(1)	4.2	1.6	2.6
Other social scientists	4,880	61	4,416	(1)	134	216	53	5.5	1.3	90.5	(1)	2.7	4.4	1.1
Engineers	5,106	1,294	3,228	(1)	142	422	20	5.8	25.3	63.2	(1)	2.8	8.3	0.4
Aeronautical/astronautical	314	62	170	(1)	(1)	64	18	0.4	19.7	54.1	(1)	(1)	20.4	5.7
Chemical	676	206	402	(1)	33	33	2	0.8	30.5	59.5	(1)	4.9	4.9	0.3
Civil	268	18	226	(1)	(1)	24	0	0.3	6.7	84.3	(1)	(1)	9.0	0.0
Electrical/electronics	705	178	464	(1)	25	38	0	0.8	25.2	65.8	(1)	3.5	5.4	0.0
Materials	1,040	409	542	(1)	(1)	89	0	1.2	39.3	52.1	(1)	(1)	8.6	0.0
Mechanical	537	112	369	(1)	29	27	0	0.6	20.9	68.7	(1)	5.4	5.0	0.0
Nuclear	184	57	117	(1)	10	(1)	0	0.2	31.0	63.6	(1)	5.4	(1)	0.0
Systems design	188	2	169	(1)	(1)	17	0	0.2	1.1	89.9	(1)	(1)	9.0	0.0
Other	1,194	250	769	(1)	45	130	0	1.4	20.9	64.4	(1)	3.8	10.9	0.0

(continued)

Appendix table 5-19. (Continued)

Field	Total employed	Business/ industry	4-year colleges and univ.	Hospitals and clinics	Nonprofit	Federal Gov't	Other/ no report	Total employed	Business/ industry	4-year colleges and univ.	Hospitals and clinics	Nonprofit	Federal Gov't	Other/ no report
	Number							Percent						
1987														
Total scientists and engineers	133,345	11,518	104,776	1,026	4,727	8,904	2,394	100.0	8.6	78.6	0.8	3.5	6.7	1.8
Total scientists	123,952	9,715	98,214	1,026	4,454	8,173	2,370	93.0	7.8	79.2	0.8	3.6	6.6	1.9
Physical scientists	26,786	4,971	18,699	38	985	1,932	161	20.1	18.6	69.8	0.1	3.7	7.2	0.6
Chemists	14,195	3,215	9,687	38	307	819	129	10.6	22.6	68.2	0.3	2.2	5.8	0.9
Physicists/astronomers	12,591	1,756	9,012	(1)	678	1,113	32	9.4	13.9	71.6	(1)	5.4	8.8	0.3
Mathematical scientists	8,436	90	7,968	(1)	2	189	187	6.3	1.1	94.5	(1)	0.0	2.2	2.2
Mathematicians	7,358	83	6,935	(1)	2	151	187	5.5	1.1	94.3	(1)	0.0	2.1	2.5
Statisticians	1,078	7	1,033	(1)	(1)	38	0	0.8	0.6	95.8	(1)	(1)	3.5	0.0
Computer/information specialists	2,774	705	1,896	(1)	116	42	15	2.1	25.4	68.3	(1)	4.2	1.5	0.5
Environmental scientists	7,294	485	4,888	(1)	361	1,381	179	5.5	6.6	67.0	(1)	4.9	18.9	2.5
Earth scientists	4,919	396	3,283	(1)	111	966	163	3.7	8.1	66.7	(1)	2.3	19.6	3.3
Oceanographers	1,341	32	959	(1)	112	238	0	1.0	2.4	71.5	(1)	8.4	17.7	0.0
Atmospheric scientists	1,034	57	646	(1)	138	177	16	0.8	5.5	62.5	(1)	13.3	17.1	1.5
Life scientists	49,169	3,117	37,980	835	2,232	4,249	756	36.9	6.3	77.2	1.7	4.5	8.6	1.5
Biological scientists	38,216	2,276	30,004	510	1,910	2,917	599	28.7	6.0	78.5	1.3	5.0	7.6	1.6
Agricultural scientists	3,298	248	1,975	(1)	30	976	69	2.5	7.5	59.9	(1)	0.9	29.6	2.1
Medical scientists	7,655	593	6,001	325	292	356	88	5.7	7.7	78.4	4.2	3.8	4.7	1.1
Psychologists	9,147	171	8,143	122	157	260	294	6.9	1.9	89.0	1.3	1.7	2.8	3.2
Social scientists	20,346	176	18,640	31	601	120	778	15.3	0.9	91.6	0.2	3.0	0.6	3.8
Economists	4,253	33	3,910	(1)	81	62	167	3.2	0.8	91.9	(1)	1.9	1.5	3.9
Sociologists/anthropologists	5,830	18	5,481	31	122	5	173	4.4	0.3	94.0	0.5	2.1	0.1	3.0
Other social scientists	10,263	125	9,249	(1)	398	53	438	7.7	1.2	90.1	(1)	3.9	0.5	4.3
Engineers	9,393	1,803	6,562	(1)	273	731	24	7.0	19.2	69.9	(1)	2.9	7.8	0.3
Aeronautical/astronautical	694	75	470	(1)	2	147	0	0.5	10.8	67.7	(1)	0.3	21.2	0.0
Chemical	1,119	271	816	(1)	29	3	0	0.8	24.2	72.9	(1)	2.6	0.3	0.0
Civil	741	12	680	(1)	(1)	46	3	0.6	1.6	91.8	(1)	(1)	6.2	0.4
Electrical/electronics	1,660	183	1,428	(1)	8	41	0	1.2	11.0	86.0	(1)	0.5	2.5	0.0
Materials	1,724	627	717	(1)	115	265	0	1.3	36.4	41.6	(1)	6.7	15.4	0.0
Mechanical	856	177	652	(1)	7	12	8	0.6	20.7	76.2	(1)	0.8	1.4	0.9
Nuclear	172	33	132	(1)	(1)	(1)	7	0.1	19.2	76.7	(1)	(1)	(1)	4.1
Systems design	280	18	260	(1)	2	(1)	0	0.2	6.4	92.9	(1)	0.7	(1)	0.0
Other	2,147	407	1,407	(1)	110	217	6	1.6	19.0	65.5	(1)	5.1	10.1	0.3

[1] These categories have fewer than 20 individuals.

Note: Researchers were counted if they said on the Survey of Doctorate Recipients that their primary or secondary work activity was basic research.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1989.

See figure 5-8.

Appendix table 5-20. Doctoral scientists and engineers employed in basic research, by sector, race, ethnic group, and gender: 1977 and 1987

Employment sector	Total employed	White	Black	American Indian	Asian	Other	Hispanic	Total employed	White	Black	American Indian	Asian	Other	Hispanic
	Number							Percent[2]						
1977														
All sectors	88,320	78,988	732	63	6,041	2,496	922	100.0	89.4	0.8	0.1	6.8	2.8	1.0
Male	79,154	70,798	598	57	5,305	2,396	854	89.6	89.6	81.7	90.5	87.8	96.0	92.6
Female	9,166	8,190	134	(1)	736	90	68	10.4	10.4	18.3	(1)	12.2	3.6	7.4
Industry	9,014	7,829	61	(1)	927	193	59	100.0	86.9	0.7	(1)	10.3	2.1	0.7
Male	8,549	7,427	55	(1)	875	188	59	94.8	94.9	90.2	(1)	94.4	97.4	100.0
Female	465	402	(1)	0	52	(1)	0	5.2	5.1	(1)	(1)	5.6	(1)	0.0
4-year colleges and universities	66,376	59,603	559	56	4,212	1,946	713	100.0	89.8	0.8	0.1	6.3	2.9	1.1
Male	59,086	53,045	458	50	3,665	1,868	653	89.0	89.0	81.9	89.3	87.0	96.0	91.6
Female	7,290	6,558	101	(1)	547	74	60	11.0	11.0	18.1	(1)	13.0	3.8	8.4
Hospitals/clinics	1,281	1,079	0	0	170	32	(1)	100.0	84.2	0.0	0.0	13.3	2.5	(1)
Male	1,095	916	0	0	147	32	(1)	85.5	84.9	0.0	0.0	86.5	100.0	(1)
Female	186	163	0	0	23	0	(1)	14.5	15.1	0.0	0.0	13.5	0.0	(1)
Nonprofit institutions	3,194	2,826	(1)	(1)	269	88	50	100.0	88.5	(1)	(1)	8.4	2.8	1.6
Male	2,675	2,350	(1)	(1)	233	82	48	83.8	83.2	(1)	(1)	86.6	93.2	96.0
Female	519	476	(1)	0	36	(1)	(1)	16.2	16.8	(1)	(1)	13.4	(1)	(1)
Federal Government	6,850	6,258	85	0	355	146	83	100.0	91.4	1.2	0.0	5.2	2.1	1.2
Male	6,350	5,853	61	0	295	141	79	92.7	93.5	71.8	0.0	83.1	96.6	95.2
Female	500	405	24	0	60	(1)	(1)	7.3	6.5	28.2	0.0	16.9	(1)	(1)
State and local governments	601	530	0	(1)	44	24	0	100.0	88.2	0.0	(1)	7.3	4.0	0.0
Male	518	452	0	(1)	39	24	0	86.2	85.3	0.0	(1)	88.6	100.0	0.0
Female	83	78	0	0	0	0	13.8	14.7	0.0	(1)	0.0	0.0	0.0	
Other	60	43	(1)	0	0	0	0	100.0	71.7	(1)	0.0	0.0	0.0	0.0
Male	50	35	(1)	0	0	0	0	83.3	81.4	(1)	0.0	0.0	0.0	0.0
Female	(1)	(1)	(1)	0	0	0	0	(1)	(1)	(1)	0.0	0.0	0.0	0.0

(continued)

Appendix table 5-20. (Continued)

Employment sector	Total employed	White	Black	American Indian	Asian	Other	Hispanic	Total employed	White	Black	American Indian	Asian	Other	Hispanic
	Number							Percent[2]						
1987														
All sectors	133,345	117,688	1,693	181	12,830	953	2,324	100.0	88.3	1.3	0.1	9.6	0.7	1.7
Male	111,853	98,677	1,277	158	10,870	853	1,959	83.9	83.8	75.4	87.3	84.7	89.5	84.3
Female	21,492	19,011	416	23	1,960	73	365	16.1	16.2	24.6	12.7	15.3	7.7	15.7
Industry	11,518	9,625	112	22	1,616	143	188	100.0	83.6	1.0	0.2	14.0	1.2	1.6
Male	10,082	8,393	100	20	1,430	139	167	87.5	87.2	89.3	90.9	88.5	97.2	88.8
Female	1,436	1,232	(1)	(1)	186	(1)	21	12.5	12.8	(1)	(1)	11.5	(1)	11.2
4-year colleges and universities	104,776	92,580	1,304	137	9,973	782	1,740	100.0	88.4	1.2	0.1	9.5	0.7	1.7
Male	87,431	77,191	957	116	8,452	699	1,439	83.4	83.4	73.4	84.7	84.7	89.4	82.7
Female	17,345	15,389	347	21	1,521	61	301	16.6	16.6	26.6	15.3	15.3	7.8	17.3
Hospitals/clinics	1,026	917	(1)	0	101	(1)	(1)	100.0	89.4	(1)	0.0	9.8	(1)	(1)
Male	849	768	0	0	76	(1)	(1)	82.7	83.8	(1)	0.0	75.2	(1)	(1)
Female	177	149	(1)	0	25	0	(1)	17.3	16.2	(1)	0.0	24.8	(1)	(1)
Nonprofit institutions	4,727	4,194	52	(1)	463	(1)	55	100.0	88.7	1.1	(1)	9.8	(1)	1.2
Male	3,690	3,295	31	(1)	348	(1)	47	78.1	78.6	59.6	(1)	75.2	(1)	85.5
Female	1,037	899	21	(1)	115	(1)	(1)	21.9	21.4	40.4	(1)	24.8	(1)	(1)
Federal Government	8,904	8,126	188	(1)	575	(1)	291	100.0	91.3	2.1	(1)	6.5	(1)	3.3
Male	7,817	7,161	159	(1)	487	(1)	265	87.8	88.1	84.6	(1)	84.7	(1)	91.1
Female	1,087	965	29	0	88	(1)	26	12.2	11.9	15.4	(1)	15.3	(1)	8.9
State and local governments	743	711	(1)	0	28	(1)	(1)	100.0	95.7	(1)	0.0	3.8	(1)	(1)
Male	626	611	0	0	(1)	0	(1)	84.3	85.9	(1)	0.0	(1)	(1)	(1)
Female	117	100	(1)	0	(1)	(1)	0	15.7	14.1	(1)	0.0	(1)	(1)	(1)
Other	139	137	0	0	(1)	0	(1)	100.0	98.6	0.0	0.0	(1)	0.0	(1)
Male	126	124	0	0	(1)	0	0	90.6	90.5	0.0	0.0	(1)	0.0	(1)
Female	(1)	(1)	0	0	0	0	(1)	0.0	(1)	0.0	0.0	(1)	0.0	(1)

[1] These categories contain fewer than 20 individuals.

[2] The first row for each sector contains horizontal percentages. The next two rows are vertical percentages, showing the percentages of males and of females within each employment sector by racial/ethnnic group.

Notes: Researchers are counted if they said on their Survey of Doctorate Recipients form that their primary or secondary work activity was basic research. Hispanics are present in various racial groups; therefore, they are not separately added into the total.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1989.

Appendix table 5-21. Proportion of doctoral researchers who remained employed in a sector, for selected time intervals between 1973 and 1987

	Elapsed time	Total[1]		4-year colleges and universities		Business/industry		Nonprofit		Federal Government	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	years	Percent retained in same sector									
1973-75	2	91	86	94	90	95	83	65	59	80	77
1975-77	2	92	88	94	90	96	93	69	66	88	74
1977-79	2	91	86	92	88	95	91	73	65	88	74
1979-81	2	92	88	93	91	95	84	74	72	91	79
1981-83	2	92	85	93	88	94	88	62	61	92	78
1983-85	2	92	88	93	90	93	86	68	70	87	84
1985-87	2	92	87	94	89	91	88	76	64	88	80
Average	2	92	87	93	90	94	87	70	65	88	78
1973-77	4	87	82	90	87	91	78	54	45	74	67
1983-87	4	87	82	90	85	85	78	62	55	77	72
1973-83	10	81	71	85	76	86	59	40	48	67	58
1977-87	10	77	72	80	75	79	73	32	33	70	66
1973-87	14	74	66	79	71	77	47	31	33	56	60

[1] Total includes other sectors, such as hospitals/clinics and the military.

Notes: Data are for doctoral scientists and engineers whose primary or secondary work activity was nonacademic basic research or academic R&D during the initial year of an interval, and who also responded at the end of the interval. There were 15,000 matched respondents for 1973-75; 6,000 of them also responded in both 1973 and 1987. Partly because of changing sampling strategies, response rates over different time intervals are not readily compared. Percentages for women are unstable in some categories that have had low numbers of women, such as business/industry during the 1970s.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1988.

See figure 5-9.

Appendix table 5-22. Proportion of doctoral scientists and engineers who remained employed in research for selected time intervals between 1973 and 1987

	Elapsed time	Scientists and engineers		Scientists		Physical scientists		Mathematical scientists		Computer/ information specialists		Environmental scientists		Life scientists		Social scientists		Engineers	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	years	Percent																	
1973-75	2	80	79	80	79	80	75	82	80	77	71	80	80	84	84	75	75	76	86
1975-77	2	71	69	72	69	73	66	72	57	68	79	75	79	77	77	59	54	67	67
1977-79	2	74	72	75	72	74	73	78	68	57	75	73	78	80	80	61	53	65	63
1979-81	2	78	77	79	77	80	79	75	72	74	74	78	87	85	83	65	65	71	71
1981-83	2	74	73	74	73	72	72	74	66	64	57	76	69	82	81	60	60	75	74
1983-85	2	75	74	75	74	76	72	74	65	64	64	78	78	80	82	64	63	71	70
1985-87	2	83	81	83	81	79	78	86	77	74	78	85	81	86	86	80	74	83	82
1973-77	4	65	61	66	60	66	55	66	57	67	59	68	69	72	69	52	44	60	81
1983-87	4	78	75	77	75	74	68	79	63	69	69	78	77	80	79	75	74	78	75
1973-83	10	58	51	58	51	56	52	54	50	57	59	59	59	64	57	48	46	52	60
1977-87	10	66	63	66	63	61	62	71	57	63	59	69	72	70	66	59	56	62	58
1973-87	14	60	55	61	55	57	50	64	55	58	62	61	66	62	58	58	55	58	61

Note: Data are for doctoral scientists and engineers whose primary or secondary work activity was nonacademic basic research or academic R&D during the initial year of an interval, and who also responded at the end of the interval. There were 15,000 matched respondents for 1973-75; 6,000 of them also responded in both 1973 and 1987. Partly because of changing sampling strategies, response rates over different time intervals are not readily compared.

SOURCE: National Research Council, Survey of Doctorate Recipients data base, special tabulations for NSF, 1988.

See text table 5-4.

Science & Engineering Indicators—1989

Appendix table 5-23. U.S. and world scientific and technical articles, by field: 1973-86

Field[1]	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	U.S. articles as a percent of all articles													
All fields	38	38	37	37	37	37	37	37	36	36	35	35	35	36
Clinical medicine	43	43	43	43	43	43	43	43	41	41	40	41	40	40
Biomedicine	39	38	39	39	39	39	40	40	40	40	39	39	38	38
Biology	46	46	45	44	42	42	43	42	38	38	38	37	37	38
Chemistry	23	22	22	22	22	21	21	21	20	21	20	21	21	22
Physics	33	33	32	31	30	31	30	30	29	28	28	27	29	30
Earth/space sciences	47	47	44	46	45	45	45	42	43	42	42	41	43	43
Engineering/technology	42	42	41	41	40	39	41	39	41	41	41	40	39	37
Mathematics	48	46	44	43	41	40	40	40	38	39	38	37	38	40
	Number of U.S. articles													
All fields	103,777	100,066	97,278	99,970	97,854	99,207	99,377	98,394	132,278	133,623	132,415	131,111	137,771	137,770
Clinical medicine	32,638	31,691	31,334	32,920	33,516	34,966	33,975	34,612	48,072	48,530	48,055	48,735	50,595	50,637
Biomedicine	16,115	15,607	15,901	16,271	16,197	16,611	17,649	17,582	21,847	22,732	22,496	22,196	24,461	24,765
Biology	11,150	10,700	10,400	10,573	9,904	9,663	10,553	9,594	14,740	14,974	14,216	14,166	13,083	13,000
Chemistry	10,474	9,867	9,222	9,337	8,852	9,266	9,182	9,250	10,880	11,758	11,010	11,137	11,585	12,313
Physics	11,721	11,945	11,363	11,502	10,995	11,015	10,995	11,415	13,053	13,255	13,021	12,691	15,903	16,360
Earth/space sciences	5,591	5,371	4,975	5,537	5,197	5,043	5,167	4,832	7,257	7,057	6,862	6,748	7,663	7,811
Engineering/technology	11,955	11,088	10,431	10,346	10,081	9,694	9,018	8,461	12,486	11,619	13,105	11,976	10,822	9,775
Mathematics	4,134	3,797	3,652	3,484	3,112	2,949	2,838	2,648	3,943	3,697	3,648	3,462	3,659	3,109
	Number of all articles													
All fields	271,513	265,130	260,908	267,354	263,700	270,128	267,953	269,556	368934	371759	373,550	369,930	389,845	387,027
Clinical medicine	76,209	74,509	73,485	76,599	77,597	81,207	78,827	80,533	116371	118186	119,325	119,094	125,532	126,463
Biomedicine	41,155	40,632	41,244	41,891	41,388	42,968	43,631	44,267	55303	57203	57,289	56,223	64,717	64,550
Biology	24,047	23,414	23,260	23,905	23,757	23,176	24,734	22,838	39232	39025	37,788	38,093	34,896	34,127
Chemistry	45,004	44,529	42,502	42,773	40,734	43,850	43,273	44,448	54432	55381	54,186	54,117	55,268	55,558
Physics	35,864	35,708	35,104	36,902	36,057	35,815	36,700	37,944	45561	47229	46,902	46,450	54,044	54,056
Earth/space sciences	11,977	11,479	11,356	12,011	11,531	11,224	11,596	11,395	16991	16660	16,508	16,334	17,834	18,351
Engineering/technology	28,617	26,600	25,664	25,146	25,063	24,588	22,182	21,459	30710	28602	32,073	30,310	28,004	26,201
Mathematics	8,639	8,259	8,293	8,127	7,573	7,298	7,011	6,673	10334	9474	9,478	9,309	9,551	7,722

[1] See appendix table 5-24 for the subfields included in these fields.

Notes: When an article is written by researchers from more than one country, that article is prorated across the number of author institutions in each country. Thus, if a given article has authors from two institutions in France and from one institution in the United States, it is counted as two-thirds of a French article and one-third of a U.S. article. Detail may not add to total because of rounding.

Data for 1973-80 are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1981-86 data are based on over 3,200 journals on the 1981 Science Citation Index Corporate Tapes.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

See text table O-1 in Overview.

Appendix table 5-24. U.S. and world scientific and technical publications, by field and subfield: 1986

Field and subfield	U.S. Publications	World Publications	U.S. as a percentage of the world
	Number	Number	Percent
Total	137,770	387,027	35.6
Clinical medicine	50,637	126,463	40.0
General and internal medicine	5,406	16,136	33.5
Allergy	325	820	39.6
Anesthesiology	446	1,425	31.3
Cancer	2,916	6,691	43.6
Cardiovascular system	2,122	4,949	42.9
Dentistry	1,154	2,613	44.2
Dermatology and venereal diseases	948	2,938	32.3
Endocrinology	1,788	4,791	37.3
Fertility	571	1,321	43.2
Gastroenterology	710	2,322	30.6
Geriatrics	373	609	61.3
Hematology	1,023	2,858	35.8
Immunology	3,997	9,303	43.0
Obstetrics and gynecology	1,057	2,459	43.0
Neurology and neurosurgery	5,465	12,747	42.9
Ophthalmology	1,249	2,653	47.1
Orthopedics	519	1,196	43.4
Arthritis and rheumatism	301	915	32.9
Otorhinolaryngology	858	1,504	57.0
Pathology	1,068	2,982	35.8
Pediatrics	1,182	2,858	41.3
Pharmacology	4,704	14,022	33.5
Pharmacy	536	2,753	19.5
Psychiatry	1,381	2,562	53.9
Radiology and nuclear medicine	2,634	5,221	50.4
Respiratory system	819	1,866	43.9
Surgery	2,379	4,641	51.3
Tropical medicine	141	772	18.3
Urology	801	1,636	49.0
Nephrology	265	724	36.6
Veterinary medicine	1,857	5,183	35.8
Addictive diseases	276	476	58.0
Hygiene and public health	1,071	2,060	52.0
Miscellaneous clinical medicine	295	458	64.5
Biomedical research	24,765	64,550	38.4
Physiology	2,299	4,801	47.9
Anatomy and morphology	253	823	30.7
Embryology	198	669	29.6
Genetics and heredity	1,627	4,537	35.9
Nutrition and dietetics	797	1,507	52.9
Biochemistry and molecular biology	8,872	22,443	39.5
Biophysics	435	1,151	37.8
Cell biology, cytology, and histology	1,675	4,681	35.8
Microbiology	1,603	4,949	32.4
Virology	814	2,083	39.1
Parasitology	446	1,393	32.0
Biomedical engineering	491	1,729	28.4
Microscopy	158	428	37.0
Miscellaneous biomedicine	486	1,134	42.8
General biomedical research	4,611	12,223	37.7

(continued)

Appendix table 5-24. (Continued)

Field and subfield	U.S. publications	World publications	U.S. as a percentage of the world
	Number	Number	Percent
Biology	13,000	34,127	38.1
General biology	142	504	28.3
General zoology	514	2,141	24.0
Entomology	1,521	2,738	55.6
Miscellaneous zoology	590	1,302	45.3
Marine biology and hydrobiology	1,160	3,780	30.7
Botany	3,398	10,197	33.3
Ecology	1,288	2,620	49.2
Agriculture and food science	3,052	7,875	38.8
Dairy animal science	1,131	2,450	46.2
Miscellaneous biology	203	520	39.0
Chemistry	12,313	55,558	22.2
Analytical chemistry	1,862	6,815	27.3
Organic chemistry	1,933	9,137	21.2
Inorganic and nuclear chemistry	889	4,637	19.2
Applied chemistry	303	1,504	20.2
General chemistry	3,075	15,472	19.9
Polymers	1,292	4,785	27.0
Physical chemistry	2,957	13,208	22.4
Physics	16,360	54,056	30.3
Chemical physics	2,340	6,252	37.4
Solid state physics	1,793	7,017	25.5
Fluids and plasmas	645	1,192	54.1
Applied physics	4,077	12,573	32.4
Acoustics	483	1,243	38.9
Optics	1,017	2,515	40.4
General physics	3,935	17,033	23.1
Nuclear and particle physics	1,962	5,944	33.0
Miscellaneous physics	109	287	38.1
Earth/space	7,811	18,351	42.6
Astronomy and astrophysics	1,746	4,329	40.3
Meteorology and atmospheric science	662	1,250	53.0
Geology	1,122	2,849	39.4
Environmental science	1,594	3,361	47.4
Earth/planetary science	2,164	5,400	40.1
Geography	0	0	0.0
Oceanography and limnology	523	1,162	45.0

(continued)

Appendix table 5-24. (Continued)

Field and subfield	U.S. publications	World publications	U.S. as a percentage of the world
	Number	Number	Percent
Engineering/technology	9,775	26,201	37.3
Chemical engineering	1,294	3,290	39.3
Mechanical engineering	1,307	3,570	36.6
Civil engineering	385	712	54.1
Electrical engineering/electronics	2,010	5,455	36.8
Miscellaneous engineering/technology	162	611	26.5
Industrial engineering	41	54	75.9
General engineering	158	317	49.8
Metals/metallurgy	962	4,417	21.8
Materials science	1,211	3,370	35.9
Nuclear technology	872	1,943	44.9
Aerospace technology	540	913	59.1
Computers	646	1,170	55.2
Library and information science	20	31	63.4
Operations research and management science	169	348	48.7
Mathematics	3,109	7,722	40.3
Probability and statistics	539	1,089	49.5
Applied mathematics	679	1,551	43.8
General mathematics	1,689	4,549	37.1
Miscellaneous mathematics	202	533	37.8

Notes: When an article is written by researchers from more than one country, that article is prorated across the number of author institutions in each country. Thus, if a given article has authors from two institutions in France and from one institution in the United States, it is counted as two-thirds of a French article and one-third of a U.S. article. Data are based on the articles, notes, and reviews in over 3,200 of the influential journals carried on the 1981 Science Citation Index Corporate Tapes.

SOURCE: Computer Horizons, Inc., Science and Engineering Indicators Literature Data Base, 1988.

Science & Engineering Indicators—1989

Appendix table 5-25. Contribution of selected countries to world literature, by field: 1981 and 1986

Field and year	World	United States	United Kingdom	West Germany	France	USSR	Japan	Canada
	Number[1]	Percent						
1981								
Total	368,934	35.9	8.3	6.3	5.0	8.0	6.8	3.9
Clinical medicine	116,371	41.3	9.8	6.4	5.2	3.3	5.1	3.4
Biomedical research	55,303	39.5	8.5	6.1	5.2	5.7	6.2	4.1
Biology	39,232	37.6	9.0	4.7	3.5	2.8	6.1	6.3
Chemistry	54,432	20.0	6.6	6.6	5.9	16.7	10.9	3.1
Physics	45,561	28.7	6.4	6.7	5.9	16.8	8.2	2.9
Earth/space sciences	16,991	42.7	8.5	4.4	4.6	10.0	2.3	5.2
Engineering/technology	30,710	40.7	8.5	7.0	3.3	7.6	9.2	4.2
Mathematics	10,334	38.2	6.1	9.0	5.6	7.6	4.3	5.1
1986								
Total	387,027	35.6	8.2	5.8	4.9	7.6	7.7	4.3
Clinical medicine	126,463	40.0	10.4	5.6	4.6	2.9	6.4	4.0
Biomedical research	64,550	38.4	8.0	5.2	5.0	8.3	7.1	4.0
Biology	34,127	38.1	9.5	4.3	3.1	2.4	6.5	8.4
Chemistry	55,558	22.2	5.7	6.9	5.6	15.1	10.7	3.1
Physics	54,056	30.3	5.6	6.9	6.5	14.7	8.6	3.1
Earth/space sciences	18,351	42.6	7.9	4.0	4.3	7.0	3.7	6.7
Engineering/technology	26,201	37.3	7.5	7.0	3.6	5.6	12.7	4.9
Mathematics	7,722	40.3	7.5	7.9	4.7	4.6	3.4	4.7

[1] These are numbers of publications.

Notes: When an article is written by researchers from more than one country, that article is prorated across the number of author institutions in each country. Thus, if there are authors from two US institutions and one French institution, the paper is counted as two-thirds of a US paper and one-third of a French paper. Data are based on over 3,200 journals on the 1981 Science Citation Index Corporate Tapes.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

Science & Engineering Indicators—1989

Appendix table 5-26. World publications with 1, 2, 3, and 4 or more authors, by field and selected years

	1973	1976	1979	1982	1984	1985	1986
				All fields			
Percentage of papers with							
1 author	33	29	24	23	21	20	19
2 authors	33	32	31	30	29	29	28
3 authors	20	21	22	22	22	22	23
4 or more authors	15	18	22	25	28	29	31
Total number of papers	294,303	294,973	284,112	384,768	382,431	402,403	398,783
Authors/paper (average)	2.27	2.43	2.61	2.74	2.85	2.91	2.98
				Clinical medicine			
Percentage of papers with							
1 author	27	23	18	17	16	15	14
2 authors	29	27	25	24	23	22	21
3 authors	22	23	23	23	22	22	22
4 or more authors	22	27	33	36	40	41	43
Total number of papers	80,080	82,284	82,197	121,180	121,593	127,905	128,537
Authors/paper (average)	2.58	2.79	3.03	3.18	3.32	3.40	3.50
				Biomedical research			
Percentage of papers with							
1 author	24	21	17	15	14	14	14
2 authors	38	36	35	32	30	29	28
3 authors	23	24	25	25	25	24	24
4 or more authors	15	19	23	27	31	32	34
Total number of papers	41,134	43,558	44,126	57,634	56,592	65,447	65,246
Authors/paper (average)	2.37	2.54	2.71	2.87	3.02	3.05	3.14
				Biology			
Percentage of papers with							
1 author	42	38	33	30	28	28	27
2 authors	35	35	36	36	36	36	36
3 authors	16	18	20	20	22	22	22
4 or more authors	8	10	12	13	15	15	15
Total number of papers	25,926	25,882	26,005	39,891	38,811	35,520	34587
Authors/paper (average)	1.93	2.04	2.17	2.23	2.32	2.31	2.34
				Chemistry			
Percentage of papers with							
1 author	17	16	15	14	13	13	13
2 authors	39	36	34	31	30	30	29
3 authors	27	28	28	28	28	28	28
4 or more authors	17	21	23	26	29	29	30
Total number of papers	47,501	47,135	44,882	56,652	55,524	57,113	57,465
Authors/paper (average)	2.52	2.64	2.74	2.83	2.93	2.92	2.96
				Physics			
Percentage of papers with							
1 author	31	28	26	25	24	22	22
2 authors	36	35	34	33	32	31	30
3 authors	20	20	21	22	22	22	22
4 or more authors	14	17	19	21	23	25	25
Total number of papers	37,536	38,516	38,579	48,606	47,934	56,016	55,840
Authors/paper (average)	2.31	2.46	2.55	2.64	2.72	2.80	2.83

(continued)

Appendix table 5-26. (Continued)

	1973	1976	1979	1982	1984	1985	1986
				Earth/space sciences			
Percentage of papers with							
1 author	48	42	39	36	33	31	30
2 authors	32	33	33	33	34	35	34
3 authors	13	15	17	17	18	18	19
4 or more authors	8	10	12	14	16	15	17
Total number of papers	12,746	12,968	12,842	17,404	16,707	18,129	18,602
Authors/paper (average)	1.87	2.01	2.12	2.21	2.33	2.32	2.39
				Engineering/technology			
Percentage of papers with							
1 author	53	51	40	36	35	32	30
2 authors	28	29	32	33	32	34	34
3 authors	12	14	17	19	19	19	21
4 or more authors	6	7	11	12	14	15	15
Total number of papers	39,784	35,825	27,959	33,271	35,349	31,845	29,996
Authors/paper (average)	1.76	1.82	2.08	2.17	2.23	2.29	2.33
				Mathematics			
Percentage of papers with							
1 author	75	73	70	66	63	62	62
2 authors	21	22	25	27	29	30	30
3 authors	3	4	4	5	6	7	7
4 or more authors	1	1	1	1	2	1	1
Total number of papers	9,597	8,808	7,523	10,131	9,924	10,428	8,510
Authors/paper (average)	1.32	1.33	1.38	1.42	1.46	1.47	1.47

Note: Data for 1973-80 are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Source Tapes of the Institute for Scientific Information; 1981-86 data are based on over 3,200 journals on the 1981 Science Citation Index Source Tapes.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

See figure 5-10.

Appendix table 5-27. Internationally coauthored articles, by field: 1976-86

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Internationally coauthored articles as a percent of all articles										
All fields	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.2	6.7	7.1	7.5
Clinical medicine	3.0	3.1	3.3	3.6	3.8	4.1	4.3	4.7	4.8	5.4	5.7
Biomedical research	4.5	4.9	5.0	5.5	5.7	6.2	6.6	6.9	7.4	7.5	8.3
Biology	3.6	3.8	4.3	4.5	4.6	4.8	4.6	5.4	6.1	6.3	6.5
Chemistry	3.2	3.8	3.6	4.1	4.3	4.7	5.1	5.3	5.7	5.8	6.1
Physics	5.8	6.5	7.1	7.5	7.8	8.5	8.9	9.2	10.0	10.2	10.5
Earth/space sciences	7.3	7.7	8.6	8.8	9.7	9.3	10.3	11.1	12.6	12.1	12.4
Engineering/technology	2.5	2.9	3.3	3.6	3.9	4.7	4.9	5.3	5.5	5.9	6.8
Mathematics	6.7	6.8	7.3	7.6	9.0	8.8	10.0	10.7	11.8	12.5	13.4
	Internationally coauthored articles										
All fields	10,561	11,338	12,317	13,227	14,057	20,414	21,745	23,275	24,799	27,522	28,936
Clinical medicine	2,314	2,440	2,709	2,837	3,032	4,725	5,084	5,554	5,751	6,735	7,179
Biomedical research	1,862	2,032	2,147	2,393	2,533	3,415	3,765	3,965	4,181	4,836	5,356
Biology	853	915	1,011	1,121	1,051	1,898	1,804	2,034	2,308	2,211	2,233
Chemistry	1,384	1,546	1,598	1,761	1,932	2,565	2,802	2,857	3,073	3,217	3,402
Physics	2,142	2,321	2,548	2,757	2,960	3,881	4,217	4,334	4,646	5,522	5,683
Earth/space sciences	830	849	963	1,021	1,108	1,586	1,709	1,827	2,065	2,154	2,278
Engineering/technology	627	721	806	803	842	1,428	1,416	1,686	1,680	1,653	1,770
Mathematics	549	515	536	534	600	914	948	1,019	1,096	1,194	1,035
	All articles										
All fields	266,453	262,993	270,124	268,007	269,569	368,956	371,767	373,548	369,930	390,069	387,190
Clinical medicine	75,929	77,487	81,211	78,828	80,546	116,385	118,188	119,326	119,095	125,718	126,586
Biomedical research	41,832	41,314	42,903	43,591	44,272	55,306	57,206	57,285	56,219	64,717	64,552
Biology	23,907	23,761	23,266	24,830	22,836	39,235	39,024	37,786	38,092	34,932	34,164
Chemistry	43,400	40,905	43,813	43,249	44,446	54,433	55,382	54,188	54,119	55,268	55,558
Physics	36,818	35,897	35,802	36,688	37,943	45,563	47,231	46,905	46,452	54,044	54,056
Earth/space sciences	11,326	11,053	11,218	11,586	11,394	16,991	16,661	16,508	16,335	17,834	18,351
Engineering/technology	25,114	25,007	24,587	22,181	21,459	30,709	28,601	32,072	30,309	28,005	26,201
Mathematics	8,127	7,569	7,325	7,053	6,673	10,334	9,473	9,478	9,309	9,551	7,722

Note: Data for 1976-1980 are based on the articles, notes, and reviews in over 2100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1981-1986 data are based on over 3200 journals on the 1981 Science Citation Index Corporate Tapes.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

Table 5-28. Internationally coauthored science and engineering articles for selected countries: 1976-86

Country	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Internationally coauthored articles as a percent of all articles by country										
West Germany	9.7	10.9	11.3	12.5	13.6	14.2	15.0	16.4	17.6	18.8	20.9
United Kingdom	10.0	10.6	11.3	12.1	13.1	13.5	13.9	14.4	15.6	15.7	16.6
Canada	12.4	12.9	14.0	14.4	15.1	17.1	17.7	17.3	18.4	18.9	19.4
France	10.3	11.4	12.5	13.1	13.7	15.2	16.7	18.0	18.9	20.5	21.3
USSR	2.0	2.5	2.4	2.8	3.0	2.8	2.9	3.0	2.9	3.2	3.3
United States	5.6	6.0	6.1	6.6	7.1	7.5	7.9	8.6	9.3	9.7	10.2
Japan	3.5	3.9	3.9	4.4	4.6	5.2	5.7	6.0	6.7	7.1	7.5
	Internationally coauthored articles										
West Germany	1,741	1,924	2,176	2,244	2,459	3,557	3,767	4,058	4,292	4,999	5,323
United Kingdom	2,574	2,633	2,784	2,889	3,159	4,492	4,626	4,847	5,150	5,545	5,789
Canada	1,532	1,599	1,715	1,812	1,819	2,718	2,861	2,862	3,183	3,494	3,636
France	1,591	1,790	1,838	2,003	2,153	3,062	3,342	3,546	3,761	4,220	4,507
USSR	432	523	528	604	637	836	900	929	869	994	982
United States	5,675	5,972	6,248	6,758	7,192	10,268	11,013	11,830	12,743	14,123	14,824
Japan	556	635	679	768	872	1,334	1,516	1,645	1,878	2,196	2,309
	All articles by country										
West Germany	17,968	17,663	19,192	17,993	18,096	25,118	25,060	24,692	24,331	26,565	25,511
United Kingdom	25,784	24,809	24,635	23,829	24,026	33,168	33,314	33,777	32,929	35,227	34,812
Canada	12,329	12,382	12,226	12,606	12,072	15,877	16,135	16,582	17,302	18,509	18,766
France	15,438	15,769	14,694	15,265	15,671	20,152	20,043	19,663	19,894	20,629	21,208
USSR	21,344	21,012	22,448	21,719	21,498	30,044	30,796	31,381	29,849	30,823	29,778
United States	102,183	100,352	102,288	102,682	101,919	137,327	139,028	138,243	137,359	144,915	145,179
Japan	15,738	16,170	17,231	17,563	18,830	25,773	26,626	27,221	27,978	30,768	30,956

Notes: Data for 1973-80 are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1981-86 data are based on over 3,200 journals on the 1981 Science Citation Index Corporate Tapes. Articles are attributed to a country if at least one author is from the country. Because of multiple counting of papers, adding together the numbers for different countries would lead to a larger count than the actual number of published papers.

SOURCE: Computer Horizons, Inc., Science and Engineering Indicators Literature Data Base, 1988.

See figure O-17 in Overview and text table 5-5.

Appendix table 5-29. International science and engineering coauthorship, by U.S. sector: 1981-86

Sector	1981	1982	1983	1984	1985	1986
	Percent of articles involving cross-national collaboration					
Academic institutions	7.7	8.0	8.6	9.3	9.7	10.2
Nonprofit institutions	5.7	6.3	6.9	7.5	8.0	8.7
FFRDCs	9.6	11.5	11.8	14.1	13.3	14.8
Federal and local government	6.0	6.6	7.4	7.9	8.3	8.6
Industry	5.5	6.5	6.5	7.0	7.9	7.9
	Number of articles involving cross-national collaboration					
Academic institutions	7,980	8,484	9,098	9,857	10,840	11,472
Nonprofit institutions	829	914	1,024	1,121	1,259	1,344
FFRDCs	614	714	756	829	928	1,031
Federal and local government	1,330	1,454	1,601	1,733	1,830	1,922
Industry	743	890	944	999	1,196	1,219
	Total articles					
Academic institutions	104,112	106,657	105,246	105,598	111,690	112,639
Nonprofit institutions	14,624	14,597	14,919	14,862	15,664	15,389
FFRDCs	6,393	6,186	6,417	5,884	6,952	6,981
Federal and local government	22,014	22,132	21,750	21,816	22,118	22,254
Industry	13,462	13,705	14,598	14,220	15,127	15,453

FFRDC = Federally funded research and development center.

Notes: Data are based on the articles, notes, and reviews in over 3,200 journals on the 1981 Science Citation Index Corporate Tapes. Articles with at least one author from the specified sector are counted in that sector. Thus, an article coauthored by two sectors will be counted twice, once for each sector. Therefore, the columns will add to a larger number of articles than the actual number published.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

Science & Engineering Indicators—1989

Appendix table 5-30. U.S. publications in science and engineering fields, by sector: 1976 and 1986

Field	Total	Academic institutions	Industry	Federal Government	Nonprofit institutions	FFRDCs	Other
				1976 (Number)			
All fields	99,430	66,019	9,648	10,521	6,890	3,384	2,960
Clinical medicine	32,821	21,498	1,156	3,768	4,594	169	1,633
Biomedical research	16,259	12,569	452	1,414	1,185	312	329
Biology	10,573	7,627	312	1,858	308	62	405
Chemistry	9,433	6,537	1,553	689	199	328	128
Physics	11,499	6,941	1,750	1,091	166	1,502	50
Earth/space sciences	5,009	3,490	243	691	137	364	84
Engineering/technology	10,345	4,165	4,076	928	248	615	321
Mathematics	3,484	3,194	106	82	61	31	10
				1986 (Number)			
All fields	137,770	95,812	11,872	12,892	9,896	4,760	2,538
Clinical medicine	50,638	34,920	2,111	5,025	6,787	254	1,541
Biomedical research	24,764	18,797	1,164	2,291	1,818	343	352
Biology	13,000	10,068	337	1,862	380	69	285
Chemistry	12,313	8,734	2,100	734	189	491	65
Physics	16,361	10,129	2,881	917	206	2,195	32
Earth/space sciences	7,811	4,985	580	1,206	285	579	177
Engineering/technology	9,774	5,369	2,579	790	180	776	81
Mathematics	3,109	2,811	121	68	49	56	4
				1976 (Percent)			
All fields	100.0	66.4	9.7	10.6	6.9	3.4	3.0
Clinical medicine	100.0	65.5	3.5	11.5	14.0	0.5	5.0
Biomedical research	100.0	77.3	2.8	8.7	7.3	1.9	2.0
Biology	100.0	72.1	3.0	17.6	2.9	0.6	3.8
Chemistry	100.0	69.3	16.5	7.3	2.1	3.5	1.4
Physics	100.0	60.4	15.2	9.5	1.4	13.1	0.4
Earth/space sciences	100.0	69.7	4.9	13.8	2.7	7.3	1.7
Engineering/technology	100.0	40.3	39.4	9.0	2.4	5.9	3.1
Mathematics	100.0	91.7	3.0	2.4	1.8	0.9	0.3
				1986 (Percent)			
All fields	100.0	69.5	8.6	9.4	7.2	3.5	1.8
Clinical medicine	100.0	69.0	4.2	9.9	13.4	0.5	3.0
Biomedical research	100.0	75.9	4.7	9.3	7.3	1.4	1.4
Biology	100.0	77.4	2.6	14.3	2.9	0.5	2.2
Chemistry	100.0	70.9	17.1	6.0	1.5	4.0	0.5
Physics	100.0	61.9	17.6	5.6	1.3	13.4	0.2
Earth/space sciences	100.0	63.8	7.4	15.4	3.6	7.4	2.3
Engineering/technology	100.0	54.9	26.4	8.1	1.8	7.9	0.8
Mathematics	100.0	90.4	3.9	2.2	1.6	1.8	0.1

FFRDC = Federally funded research and development center.

Notes: Data for 1976 are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1986 data are based on over 3,200 journals on the 1981 Science Citation Index Corporate Tapes. When an article is written by researchers from more than one sector, the article is prorated among sectors, based on the number of author institutions in each sector.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

Science & Engineering Indicators—1989

Appendix table 5-31. Coauthorship among U.S. sectors: 1973, 1976, and 1982-86

	1973	1976	1982	1983	1984	1985	1986	1973	1976	1982	1983	1984	1985	1986
	Number							Percent						
Industry articles coauthored with														
All sectors	2,048	2,166	4,166	4,434	4,590	5,150	5,455	17.0	19.9	30.4	30.4	32.3	34.0	35.3
Nonprofit institutions	160	137	364	404	440	514	549	1.3	1.3	2.7	2.8	3.1	3.4	3.6
FFRDCs	69	83	268	352	362	380	455	0.6	0.8	2.0	2.4	2.5	2.5	2.9
Government	423	522	861	965	922	1,011	1,135	3.5	4.8	6.3	6.6	6.5	6.7	7.3
Academic institutions	1,542	1,592	3,297	3,386	3,584	4,063	4,283	12.8	14.6	24.1	23.2	25.2	26.9	27.7
Nonprofit articles coauthored with														
All sectors	4,835	4,950	8,279	8,472	8,410	9,097	9,039	50.0	51.9	56.7	56.8	56.6	58.1	58.7
Industry	160	137	364	404	440	514	549	1.7	1.4	2.5	2.7	3.0	3.3	3.6
FFRDCs	36	60	107	107	125	132	106	0.4	0.6	0.7	0.7	0.8	0.8	0.7
Government	708	727	1,138	1,157	1,080	1,265	1,284	7.3	7.6	7.8	7.8	7.3	8.1	8.3
Academic institutions	4,392	4,515	7,627	7,798	7,718	8,326	8,298	45.4	47.4	52.3	52.3	51.9	53.2	53.9
FFRDC articles coauthored with														
All sectors	1,371	1,438	2,509	2,682	2,709	2,995	3,277	39.8	44.0	40.6	41.8	46.0	43.1	46.9
Industry	69	83	268	352	362	380	455	2.0	2.5	4.3	5.5	6.2	5.5	6.5
Nonprofit institutions	36	60	107	107	125	132	106	1.0	1.8	1.7	1.7	2.1	1.9	1.5
Government	88	109	248	291	309	316	382	2.5	3.3	4.0	4.5	5.3	4.5	5.5
Academic institutions	1,193	1,250	2,095	2,159	2,186	2,406	2,637	34.6	38.3	33.9	33.6	37.1	34.6	37.8
Government articles coauthored with														
All sectors	7,078	7,729	11,545	11,474	11,598	11,959	12,366	39.8	45.6	52.2	52.8	52.2	54.1	55.6
Industry	423	522	861	965	922	1,011	1,135	2.4	3.1	3.9	4.4	4.2	4.6	5.1
Nonprofit institutions	708	727	1,138	1,157	1,080	1,265	1,284	4.0	4.3	5.1	5.3	5.0	5.7	5.8
FFRDCs	88	109	248	291	309	316	382	0.5	0.6	1.1	1.3	1.4	1.4	1.7
Academic institutions	6,200	6,777	10,197	10,028	10,249	10,456	10,809	34.9	39.9	46.1	46.1	47.0	47.3	48.6
Academic articles coauthored with														
All sectors	12,988	13,858	21,938	23,371	22,424	23,753	24,388	17.1	18.4	20.6	20.9	21.2	21.3	21.7
Industry	1,542	1,592	3,297	3,386	3,584	4,063	4,283	2.0	2.1	3.1	3.2	3.4	3.6	3.8
Nonprofit institutions	4,392	4,515	7,627	7,798	7,718	8,326	8,298	5.8	6.0	7.2	7.4	7.3	7.5	7.4
FFRDCs	1,193	1,250	2,095	2,159	2,186	2,406	2,637	1.6	1.7	2.0	2.1	2.1	2.2	2.3
Government	6,200	6,777	10,197	10,028	10,249	10,456	10,809	8.2	9.0	9.6	9.5	9.7	9.4	9.6

FFRDC = Federally funded research and development center.

Notes: Data for 1973 and 1976 are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1982-1986 data are based on over 3,200 journals on the 1981 Science Citation Index Corporate Tapes. An article is counted from a sector if one or more authors is from the sector. Partly because some articles have authors from more than two sectors, the "All sectors" total is slightly less than the sum of the four individual sector coauthorships.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

See figure 5-11.

Science & Engineering Indicators—1989

Appendix table 5-32. Academic coauthorship of industry articles, by science and engineering field for selected years

	1973	1976	1979	1981	1982	1983	1984	1985	1986
	Academia/industry coauthored articles as a percent of all industry articles								
All fields	13	15	17	22	24	23	25	27	28
Clinical medicine	21	21	26	30	34	33	35	40	37
Biomedical research	19	25	26	35	37	35	35	39	38
Biology	19	27	31	39	46	42	37	44	44
Chemistry	9	11	11	13	17	15	16	16	18
Physics	13	16	17	20	21	23	25	23	23
Earth/space sciences	29	26	26	34	35	33	36	33	36
Engineering/technology	9	10	12	16	17	16	17	18	20
Mathematics	29	27	37	43	35	42	42	43	40
	Academia/industry coauthored articles								
All fields	1,542	1,592	1,710	2,905	3,297	3,386	3,584	4,063	4,283
Clinical medicine	322	292	356	636	768	779	916	1,080	1,150
Biomedical research	116	143	154	276	305	334	391	534	654
Biology	82	100	125	176	246	210	213	242	217
Chemistry	183	184	184	269	357	328	327	365	423
Physics	244	319	327	508	575	603	650	806	825
Earth/space sciences	102	80	101	207	241	222	251	286	316
Engineering/technology	455	439	424	746	732	811	757	645	629
Mathematics	37	35	39	89	73	100	79	105	69
	Articles with one or more industry authors								
All fields	12,053	10,885	10,056	13,462	13,705	14,598	14,220	15,127	15,453
Clinical medicine	1,566	1,390	1,391	2,086	2,257	2,394	2,608	2,725	3,102
Biomedical research	613	582	601	782	824	966	1,109	1,376	1,715
Biology	435	376	401	452	533	500	571	553	490
Chemistry	1,975	1,693	1,660	1,999	2,124	2,143	2,007	2,230	2,415
Physics	1,907	2,020	1,948	2,559	2,713	2,623	2,553	3,511	3,590
Earth/space sciences	352	312	389	606	691	664	698	875	884
Engineering/technology	5,076	4,387	3,562	4,770	4,356	5,075	4,483	3,612	3,085
Mathematics	130	127	105	208	208	235	189	245	172

Notes: Data before 1981 are based on the articles, notes, and reviews in over 2100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information; 1981-1986 data are based on over 3200 journals on the 1981 Science Citation Index Corporate Tapes. All articles with one or more industry authors are counted as industry articles.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, 1988.

See figure O-26 in Overview.

Science & Engineering Indicators—1989

Appendix table 5-33. Citations in U.S. papers to papers from selected countries, by field and citing year: 1977-86

	Publication year of citing papers									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Percent of citations in U.S. papers to									
	France									
All fields	2.1	2.2	2.2	2.1	2.3	2.4	2.5	2.5	2.6	2.6
Clinical medicine	1.4	1.4	1.5	1.5	1.7	1.7	1.8	1.8	1.8	1.9
Biomedical research	2.3	2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.6	2.7
Biology	1.0	1.1	1.2	1.1	1.2	1.1	1.2	1.0	0.9	0.9
Chemistry	3.1	3.6	3.2	3.1	3.1	3.5	3.5	3.6	3.6	3.6
Physics	3.6	3.8	3.9	3.6	3.8	3.9	4.1	4.2	4.7	4.6
Earth/space sciences	2.1	2.2	2.1	2.1	2.1	2.2	2.4	2.5	2.6	2.4
Engineering/technology	1.3	1.4	1.6	1.2	1.7	1.9	1.8	2.2	1.8	1.8
Mathematics	3.5	3.5	3.3	2.8	2.9	2.9	3.7	2.8	3.1	3.8
	Japan									
All fields	2.1	2.3	2.3	2.5	2.7	2.8	2.9	3.0	3.3	3.5
Clinical medicine	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.4	2.6
Biomedical research	2.1	2.5	2.3	2.4	2.6	2.7	3.0	3.3	3.6	3.9
Biology	1.8	2.0	2.1	1.9	2.2	1.9	1.8	2.1	2.2	2.0
Chemistry	4.5	5.3	5.1	5.0	5.4	5.9	6.3	6.1	6.8	6.9
Physics	2.5	2.4	2.6	3.4	3.6	4.0	3.9	3.9	4.1	4.2
Earth/space sciences	0.9	0.8	0.9	1.1	1.0	1.2	1.1	1.1	1.0	1.3
Engineering/technology	2.1	2.7	2.7	3.4	3.6	3.9	3.7	4.3	4.3	4.1
Mathematics	1.7	1.5	1.2	1.7	2.2	1.8	2.0	2.4	1.7	1.7
	United Kingdom									
All fields	7.3	7.3	7.0	6.7	6.3	6.1	5.8	6.0	5.8	5.9
Clinical medicine	7.5	7.4	7.1	6.7	6.3	6.2	6.2	6.2	6.2	6.1
Biomedical research	7.9	7.8	7.7	7.1	6.5	6.3	5.9	6.1	5.9	6.4
Biology	6.7	6.6	6.6	6.7	6.8	6.3	6.3	6.1	5.6	5.7
Chemistry	7.9	7.7	7.4	7.1	6.5	6.3	6.2	6.4	5.8	6.0
Physics	5.8	5.4	5.4	5.3	5.1	4.7	4.5	5.0	4.7	4.5
Earth/space sciences	6.7	7.6	6.9	6.7	6.6	6.4	5.4	6.3	5.0	5.5
Engineering/technology	6.7	7.5	7.1	6.3	5.7	5.3	4.9	4.6	5.0	4.9
Mathematics	5.1	6.0	6.5	5.6	5.6	3.9	5.9	6.0	5.6	5.3
	West Germany									
All fields	2.8	2.9	3.0	3.2	3.2	3.2	3.2	3.3	3.4	3.4
Clinical medicine	1.6	1.7	1.8	1.7	1.8	1.8	1.8	1.9	2.0	1.9
Biomedical research	3.1	3.5	3.3	3.6	3.7	3.5	3.6	3.7	3.5	3.3
Biology	1.9	1.4	1.9	2.2	2.3	2.2	2.3	2.1	2.2	2.0
Chemistry	4.9	5.0	4.9	5.2	5.0	5.3	5.0	4.8	4.9	5.8
Physics	4.9	5.3	5.9	6.0	6.2	6.4	6.1	6.4	6.2	6.6
Earth/space sciences	1.9	1.9	1.9	2.2	2.1	2.1	2.6	2.9	3.1	3.0
Engineering/technology	2.6	2.3	2.5	2.9	2.7	2.8	2.3	3.0	3.1	3.2
Mathematics	2.7	3.2	3.9	4.1	3.9	3.2	3.7	3.2	3.8	3.4
	United States									
All fields	71.5	70.8	71.4	71.3	71.2	71.3	71.8	71.2	71.0	70.5
Clinical medicine	73.9	73.5	73.9	74.4	74.3	74.4	74.5	74.2	73.6	73.0
Biomedical research	70.8	69.2	70.9	70.8	70.7	71.1	71.4	71.1	71.8	71.4
Biology	74.2	74.8	72.5	72.4	71.7	73.4	73.7	73.7	73.6	74.4
Chemistry	61.2	59.7	61.6	61.5	62.3	61.3	61.2	63.1	62.5	60.7
Physics	69.4	69.3	68.2	67.4	66.4	66.0	66.8	64.9	64.6	64.3
Earth/space sciences	76.8	75.7	76.2	74.5	75.7	75.6	77.5	74.6	75.3	75.5
Engineering/technology	75.3	75.2	74.4	74.7	74.2	75.1	75.3	74.2	73.4	73.4
Mathematics	74.0	72.9	73.6	72.0	71.8	73.5	70.2	70.0	71.3	71.6

(continued)

Appendix table 5-33. (Continued)

	Publication year of citing papers									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Percent of citations in U.S. papers to									
	Non-United States									
All fields	28.5	29.2	28.6	28.7	28.8	28.7	28.2	28.8	29.0	29.5
Clinical medicine	26.1	26.5	26.1	25.6	25.7	25.6	25.5	25.8	26.4	27.0
Biomedical research	29.2	30.8	29.1	29.2	29.3	28.9	28.6	28.9	28.2	28.6
Biology	25.8	25.2	27.5	27.6	28.3	26.6	26.3	26.3	26.4	25.6
Chemistry	38.8	40.3	38.4	38.5	37.7	38.7	38.8	36.9	37.5	39.3
Physics	30.6	30.7	31.8	32.6	33.6	34.0	33.2	35.1	35.4	35.7
Earth/space sciences	23.2	24.3	23.8	25.5	24.3	24.4	22.5	25.4	24.7	24.5
Engineering/technology	24.7	24.8	25.6	25.3	25.8	24.9	24.7	25.8	26.6	26.6
Mathematics	26.0	27.1	26.4	28.0	28.2	26.5	29.8	30.0	28.7	28.4
	Number of citations in U.S. papers to									
	France									
All fields	8,904	8,840	9,549	9,145	10,359	11,081	11,805	11,383	12,484	12,768
Clinical medicine	2,185	2,202	2,311	2,325	2,705	2,702	2,879	2,800	2,960	2,998
Biomedical research	2,636	2,213	2,907	2,913	3,171	3,468	3,532	3,470	3,851	4,213
Biology	252	252	291	278	316	315	333	294	224	220
Chemistry	1,294	1,505	1,276	1,226	1,358	1,582	1,506	1,525	1,500	1,518
Physics	1,768	1,820	1,820	1,665	1,928	2,053	2,275	2,168	2,935	2,906
Earth/space sciences	475	540	623	500	551	612	910	763	701	647
Engineering/technology	145	155	195	142	226	255	244	275	212	171
Mathematics	149	153	126	98	104	95	124	87	100	96
	Japan									
All fields	8,670	9,190	9,835	10,552	12,143	13,096	13,778	13,781	16,320	17,044
Clinical medicine	2,261	2,420	2,504	2,824	3,151	3,270	3,418	3,347	4,062	4,151
Biomedical research	2,389	2,343	2,880	2,975	3,390	3,578	4,037	4,258	5,503	6,046
Biology	436	482	518	446	609	545	499	589	552	465
Chemistry	1,836	2,203	2,039	2,010	2,328	2,688	2,678	2,571	2,796	2,961
Physics	1,238	1,169	1,236	1,581	1,852	2,095	2,142	2,052	2,579	2,615
Earth/space sciences	210	202	283	255	258	318	430	348	281	366
Engineering/technology	229	305	328	402	478	542	508	540	494	398
Mathematics	72	66	47	60	77	60	66	75	53	43
	United Kingdom									
All fields	30,855	29,393	30,659	28,468	28,590	28,167	27,951	27,676	28,218	28,553
Clinical medicine	11,561	11,583	10,889	10,334	10,261	10,084	10,136	9,974	10,375	9,919
Biomedical research	9,034	7,434	9,484	8,699	8,393	8,374	7,929	8,019	8,933	9,830
Biology	1,611	1,566	1,617	1,619	1,877	1,753	1,785	1,707	1,402	1,323
Chemistry	3,262	3,200	2,933	2,812	2,785	2,854	2,662	2,681	2,403	2,555
Physics	2,882	2,620	2,555	2,449	2,580	2,472	2,485	2,587	2,981	2,819
Earth/space sciences	1,550	1,874	2,056	1,628	1,736	1,772	2,079	1,946	1,365	1,496
Engineering/technology	738	852	880	730	760	729	679	573	580	477
Mathematics	218	264	245	197	198	129	196	188	178	134
	West Germany									
All fields	11,783	11,762	13,058	13,526	14,688	14,976	15,521	15,292	16,444	16,375
Clinical medicine	2,503	2,638	2,756	2,686	2,978	2,895	3,013	3,101	3,387	3,070
Biomedical research	3,548	3,285	4,042	4,416	4,721	4,651	4,877	4,874	5,251	5,084
Biology	456	342	473	525	620	615	667	599	555	462
Chemistry	1,998	2,064	1,960	2,076	2,142	2,405	2,159	2,030	2,024	2,456
Physics	2,441	2,556	2,787	2,796	3,179	3,341	3,355	3,324	3,904	4,105
Earth/space sciences	440	473	580	540	555	582	1,011	886	842	805
Engineering/technology	284	262	311	343	356	380	317	377	361	307
Mathematics	114	143	149	143	137	106	123	100	121	86

(continued)

Appendix table 5-33. (Continued)

	Publication year of citing papers									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Number of citations in U.S. papers to									
	United States									
All fields	301,986	286,737	310,795	304,202	324,883	331,920	344,541	326,962	347,926	340,365
Clinical medicine	114,216	114,488	113,852	114,783	121,210	121,248	122,061	118,522	123,698	117,768
Biomedical research	80,964	65,500	87,657	86,865	91,055	93,828	95,660	92,907	108,371	109,834
Biology	17,817	17,788	17,875	17,447	19,695	20,567	20,945	20,735	18,380	17,285
Chemistry	25,202	24,850	24,484	24,486	26,903	27,935	26,182	26,552	25,696	25,877
Physics	34,534	33,597	32,175	31,405	33,890	34,729	36,956	33,716	40,561	40,232
Earth/space sciences	17,766	18,769	22,772	17,966	19,788	20,834	30,006	23,103	20,502	20,488
Engineering/technology	8,344	8,522	9,190	8,711	9,804	10,348	10,402	9,217	8,453	7,081
Mathematics	3,142	3,223	2,790	2,539	2,539	2,430	2,328	2,210	2,265	1,800
	World (U.S. plus non-U.S.)									
All fields	422,396	404,828	435,222	426,790	456,408	465,694	480,125	459,029	489,875	482,986
Clinical medicine	154,614	155,696	154,013	154,354	163,077	162,898	163,855	159,695	168,111	161,427
Biomedical research	114,404	094,703	123,646	122,617	128,815	131,956	133,958	130,629	150,947	153,882
Biology	24,018	23,796	24,649	24,101	27,450	28,023	28,420	28,116	24,964	23,242
Chemistry	41,176	41,638	39,729	39,806	43,152	45,575	42,764	42,098	41,135	42,607
Physics	49,731	48,461	47,160	46,597	51,037	52,598	55,290	51,962	62,809	62,538
Earth/space sciences	23,126	24,786	29,886	24,126	26,126	27,560	38,706	30,955	27,219	27,127
Engineering/technology	11,080	11,328	12,347	11,663	13,218	13,777	13,819	12,418	11,513	9,649
Mathematics	4,248	4,420	3,791	3,528	3,534	3,308	3,314	3,157	3,177	2,514

Notes: Data are based on the articles, notes, and reviews in over 2100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information. Cited years were on a 2-year lag, 3-year rolling cycle after the year of the citing paper. For example, for the 1986 citing year, only papers published in 1982-84 were counted as cited papers.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, special tabulations for NSF, 1988.

See text table 5-6.

Appendix table 5-34. Relative citation ratios for U.S. and foreign papers, by field: 1977-86

	Publication year of citing papers									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Relative citation ratio[1]									
	Non-U.S. citations to U.S. papers									
All fields	1.00	0.99	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.01
Clinical medicine	0.98	0.99	0.98	0.99	0.98	0.98	0.99	0.98	0.98	0.96
Biomedical research	1.07	1.02	1.07	1.05	1.03	1.03	1.03	1.02	1.03	1.04
Biology	0.67	0.68	0.69	0.68	0.68	0.71	0.70	0.70	0.65	0.67
Chemistry	1.12	1.11	1.13	1.14	1.14	1.17	1.15	1.16	1.13	1.14
Physics	1.16	1.16	1.16	1.12	1.14	1.13	1.14	1.10	1.14	1.15
Earth/space sciences	1.04	1.06	1.05	1.05	1.05	1.06	1.09	1.10	1.09	1.10
Engineering/technology	0.82	0.81	0.80	0.80	0.83	0.83	0.83	0.78	0.73	0.74
Mathematics	0.81	0.85	0.82	0.85	0.85	0.87	0.85	0.86	0.83	0.93
	U.S. citations to U.S. papers									
All fields	1.90	1.89	1.92	1.92	1.93	1.94	1.95	1.94	1.93	1.92
Clinical medicine	1.73	1.72	1.72	1.73	1.72	1.73	1.74	1.75	1.75	1.74
Biomedical research	1.83	1.79	1.82	1.82	1.79	1.79	1.78	1.76	1.77	1.76
Biology	1.63	1.67	1.67	1.71	1.71	1.74	1.74	1.72	1.70	1.72
Chemistry	2.75	2.73	2.83	2.86	2.92	2.92	2.91	2.95	2.93	2.85
Physics	2.12	2.16	2.19	2.19	2.19	2.19	2.22	2.16	2.17	2.19
Earth/space sciences	1.68	1.66	1.69	1.64	1.69	1.72	1.79	1.74	1.74	1.73
Engineering/technology	1.82	1.83	1.83	1.86	1.85	1.89	1.86	1.82	1.75	1.76
Mathematics	1.61	1.65	1.73	1.74	1.77	1.83	1.78	1.80	1.83	1.87
	U.S. citations to non-U.S. papers									
All fields	0.46	0.47	0.46	0.46	0.46	0.45	0.45	0.46	0.46	0.47
Clinical medicine	0.46	0.46	0.46	0.45	0.45	0.45	0.45	0.45	0.46	0.47
Biomedical research	0.48	0.50	0.48	0.48	0.48	0.48	0.48	0.48	0.47	0.48
Biology	0.47	0.46	0.49	0.48	0.49	0.46	0.46	0.46	0.47	0.45
Chemistry	0.50	0.52	0.49	0.49	0.48	0.49	0.49	0.47	0.48	0.50
Physics	0.45	0.45	0.46	0.47	0.48	0.49	0.47	0.50	0.50	0.50
Earth/space sciences	0.43	0.45	0.43	0.47	0.44	0.43	0.40	0.44	0.44	0.43
Engineering/technology	0.42	0.42	0.43	0.42	0.43	0.41	0.42	0.44	0.46	0.46
Mathematics	0.48	0.49	0.46	0.48	0.47	0.44	0.49	0.49	0.47	0.46

[1] Also called "relative citation index," this measures the share of citations a country, sector, etc., gets relative to the share of the world's literature it produces.

Notes: Data are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information. Citations are counted in a 2-year-lag, 3-year rolling cycle. For example, for citing year 1982, citations to publications in years 1978-80 are counted.

SOURCE: Computer Horizons, Inc., Science & Engineering Indicators Literature Data Base, special tabulations for NSF, 1989.

Science & Engineering Indicators—1989

Appendix table 5-35. Cross-sector citations in U.S. papers: 1977-86

	Year of citing papers									
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
	Relative citation ratio[1]									
FFRDC citations to										
FFRDCs	10.82	10.81	10.53	11.76	12.24	12.94	12.28	13.01	12.58	12.56
Federal Government	0.56	0.60	0.64	0.54	0.47	0.59	0.70	0.57	0.63	0.64
Academic institutions	0.78	0.78	0.77	0.77	0.75	0.72	0.71	0.74	0.73	0.75
Industry	0.65	0.64	0.68	0.67	0.79	0.85	0.85	0.77	0.79	0.80
Nonprofit institutions	0.35	0.44	0.37	0.36	0.34	0.36	0.36	0.32	0.33	0.33
Federal Government citations to										
FFRDCs	0.63	0.53	0.60	0.51	0.51	0.57	0.74	0.54	0.53	0.56
Federal Government	3.14	3.15	3.27	3.36	3.31	3.35	3.40	3.54	3.56	3.54
Academic institutions	0.75	0.77	0.78	0.78	0.78	0.77	0.75	0.75	0.75	0.74
Industry	0.42	0.47	0.40	0.36	0.40	0.43	0.47	0.43	0.46	0.49
Nonprofit institutions	1.14	1.03	1.00	0.99	0.98	0.98	0.98	1.03	1.04	1.02
Academic citations to										
FFRDCs	0.77	0.68	0.61	0.64	0.66	0.69	0.72	0.68	0.67	0.74
Federal Government	0.77	0.77	0.80	0.81	0.81	0.83	0.86	0.85	0.84	0.82
Academic institutions	1.18	1.18	1.18	1.18	1.17	1.15	1.14	1.14	1.13	1.13
Industry	0.35	0.35	0.35	0.35	0.38	0.40	0.43	0.41	0.43	0.48
Nonprofit institutions	1.02	0.97	0.93	0.93	0.94	0.96	0.97	1.01	1.03	1.01
Industry citations to										
FFRDCs	1.11	1.02	1.03	1.00	0.90	1.03	1.19	1.04	1.26	1.22
Federal Government	0.74	0.66	0.77	0.70	0.72	0.68	0.76	0.78	0.82	0.81
Academic institutions	0.60	0.59	0.59	0.60	0.59	0.60	0.60	0.62	0.63	0.66
Industry	4.35	4.75	4.69	4.89	5.12	5.11	4.93	4.72	4.46	4.21
Nonprofit institutions	0.43	0.41	0.44	0.41	0.40	0.44	0.49	0.61	0.61	0.62
Nonprofit citations to										
FFRDCs	0.33	0.23	0.19	0.23	0.24	0.29	0.34	0.27	0.24	0.25
Federal Government	1.00	0.99	1.04	1.00	1.00	1.01	0.98	0.99	0.98	0.94
Academic institutions	0.85	0.87	0.88	0.89	0.88	0.87	0.87	0.86	0.86	0.85
Industry	0.23	0.21	0.21	0.21	0.25	0.27	0.28	0.29	0.26	0.30
Nonprofit institutions	4.02	3.94	3.71	3.71	3.75	3.62	3.63	3.73	3.84	3.82

(continued)

DOCUMENT RESUME

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ABSTRACT

The norm of "universalism" determines maintenance of science in society by preventing restriction of access to the field on grounds other than competence. Inferences for this theory are made on the basis of a test-case of the proposition that differential socialization predicts entry into the scientific talent pool. The Early Childhood Women in Science Scale (ECWiSS) was employed in a pilot administration to a sample of 791 students from New York City schools. Controlling for ability, significant differences in attitude were associated with various gender, age/grade, and socioeconomic status with gender explaining the greatest proportion (11%) of the total variance (16%). The findings suggest moderate normative compliance and the salience of including early childhood as a critical consideration in models of ascriptive and meritocratic processes affecting recruitment to science. (Author)

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UNIVERSALISM IN SCIENCE: AN EMPIRICAL INVESTIGATION OF ATTITUDES TOWARD WOMEN IN SCIENCE*

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UNIVERSALISM IN SCIENCE:
AN EMPIRICAL INVESTIGATION OF ATTITUDES TOWARD WOMEN IN SCIENCE

Abstract

The norm of *universalism* determines maintenance of science in society by preventing restriction of access to the field on grounds other than competence. Inferences for this theory are made on the basis of a test-case of the proposition that differential socialization predicts entry into the scientific *talent pool.* The Early Childhood Women in Science Scale (ECWiSS) was employed in a pilot administration to a purposive sample of 791 students from New York City schools. Controlling for ability, significant differences in attitude were associated with variations in gender, age/grade, and socioeconomic status with gender explaining the greatest proportion (11%) of the total variance (16%). The findings suggest moderate normative compliance and the salience of including early childhood as a critical consideration in models of ascriptive and meritocratic processes affecting recruitment to science.

UNIVERSALISM IN SCIENCE: AN EMPIRICAL INVESTIGATION OF ATTITUDES TOWARD WOMEN IN SCIENCE

Abstract

This research provides evidence to support the claim that the norm of *universalism* in science, by preventing restriction of access to the field on grounds other than competence, is a functional prerequisite for the maintenance of science in society. Inferences for theory are made on the basis of a test-case of the proposition that differential socialization predicts entry into the scientific talent pool (high ability students whose positive attitudes toward science are evidenced at or before ninth grade). Given that the pool from which scientists emerge, includes talented youngsters who have positive attitudes toward science, the contribution of ascriptive characteristics to attitudes toward science, once ability is controlled, is investigated. A 27-item instrument, the Early Childhood Women in Science Scale (ECWiSS), containing 4-point Likert-type measures of attitudes toward women scientists, was employed in a pilot administration to a purposive sample of 791 kindergarten through fourth grade students from New York City schools. The null hypothesis that attitudes, holding ability constant, will be the same across all attributes of the independent variables, was tested at three probability levels, using analysis of variance (ANOVA). Regression analyses showed that ascriptive factors explain only 16 percent of the variance in attitudes toward women in science and that gender accounts for approximately 11 percent and greatest proportion of the total variance. Three-dimensions of attitudes were identified by employing a principal-components analysis (*role specific self-concept, home-related sex-role conflict, and work-related sex-role conflict*) and significant differences in this measure were associated with variations in socialization. On the average, girls show more positive attitudes than boys, regardless of race, age, and socioeconomic status. Attitudes toward women in science are also more positive for middle class- versus working-class students, for children from intact households as compared to children living in single-parent homes, and for students attending private schools in contrast to students enrolled in public schools. White boys from low income families are the least likely to agree with the image of the female scientist. The findings indicate the overall approval of *universalism* in American culture, that *deviance is relatively rare*, and that discrimination operates to a small degree to restrict the pool from which scientists are recruited. The results also suggest the value of including early childhood as a critical consideration in models of the ascriptive and/or meritocratic processes affecting recruitment to science. More generally, by specifying the precise conditions under which *universalism* operates, the results extend our knowledge of the normative determinants of the maintenance of science.

UNIVERSALISM IN SCIENCE: AN EMPIRICAL INVESTIGATION OF ATTITUDES TOWARD WOMEN IN SCIENCE*

The debate over the normative structure of science involves those proponents who advocate a Mertonian (structural-functional) model of the ethos of science, and those who advocate a Kuhnian model (phenomenological). Merton (1942), refers to the ethos of science as four institutional imperatives, or norms — rules of conduct which regulate the behavior and interrelations of scientists. To *universalism*, *organized scepticism*, *disinterestedness*, and *communism*, have been added *individualism, faith in rationality* and *emotional neutrality*, and *originality* (Barber, 1952). These are not binding technical prescriptions or proscriptions, but are beliefs about what is right and good, and on which the growth and advancement of science depends. For adherents of the Mertonian school, the main objective of empirical research is to show that the scientific ethos operates as the normative culture of science in which deviance is relatively rare (Storer, 1966). Kuhnian adversaries of this approach seek to prove that the norms posited by Merton are not institutionalized or universally adhered to and that the advancement of scientific knowledge is not contingent upon conformity to the scientific ethos, but is rather the outcome of indeterminate norms. More empirical evidence for assessing the validity of the ethos of science as the standard of scientists' conduct, is required if the Mertonian paradigm, virtually unchallenged for three decades, is to retain recognition as a powerful explanatory model (Toren, 1983).

This investigation is intended as an empirical observation of normative compliance. It focuses its attention on *universalism*. Studies of this type have included those which examine the distribution of rewards (i.e., Cole and Cole, 1973), and those which survey the attitudes of scientists toward the norms of science (i.e., Crane, 1972). This study, however, will utilize the concept of *universalism* in its broader sense — in the sense that Barber (1952) referred to as "a value of science which is connected directly with the larger morality of liberal society (p. 98)." Certain features of liberal and authoritarian societies make them relatively more or less favorable to the continued advance of science. The approval culture places upon *universalism* is directly associated with the maintenance of a high level of scientific activity. The value has a secularized meaning of the Christian ideal of the brotherhood of persons in God so that ideally, all persons are free to find an occupation commensurate with their merits. At the societal level, most Americans accept the inevitability of stratification (the unequal distribution of wealth, power and prestige), but still claim they believe in equality. By this they mean that the rules determining who succeeds and who fails should be fair (Jencks, 1971). Most Americans also believe that education meritocratically encourages social mobility. Access to educational resources reduces the significance of ascriptive criteria for selection into elite occupations such as science (Lantz, West & Elliott, 1976; Bills, 1988). The consequences of ascriptive-based stratification are especially for the development and maintenance of science in society (Barber, 1952; Merton, 1973). That is, the norm of *universalism* is violated when occupational selection into scientific careers is in terms of *particularistic* criteria such as strategies which insure inclusion of persons who are the same race/ethnicity and gender, and less by *universalistic* criteria such as by the actual ability of individuals to meet the skill demands of the work. For example, stratification by gender is manifested by the aggregate underrepresentation of women in science (National Science Foundation, 1986). Women make up only thirteen percent of the science and engineering workforce and are most underrepresented in engineering and the physical sciences (National Science Foundation, 1984), despite the fact that increasingly more women enter law and medicine (Vetter, 1986). A current issue of the *American Psychologist* (American Psychological Association, 1988, p. 221) also illustrates gender stratification. On a list of seventy-seven scientists acknowledged as recipients of awards for distinguished scientific contributions from 1956 to 1987, only five were women, two of which were named as the second of two co-contributors. To explain this phenomenon, we have to believe either in the inherent inability of women to do science or we have to turn to an examination of the social factors, specifically the operation of *universalism* in the broader society and in the scientific community, which restrict their access and contribution to the field. That is, how does compliance at the societal level relate to compliance within the community of scientists? If the norm in the wider cultural context is not adhered to, then compliance within the scientific community seems impossible because the pool from which scientists emerge is already restrictive. We are led to consider whether ascriptive characteristics such as gender, race, age, and socioeconomic status, restrict the science talent pool.

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* The term *science* as used in this paper, refers to those occupations broadly defined by the National Science (1986) — the physical, computer environmental, life, and social sciences, psychology and engineering.

Adherents of the normative approach have typically defined research problems which identify internalized attitudes as dispositions to act in accordance with the rules. Measuring the attitudes of young children should therefore reflect the internalized value of *universalism*.

Literature on the early socialization of scientists has been focused on the adolescent formation of interest and abilities in science and mathematics as determinants of later college major and career choice in scientific fields (Eiduson and Beckman, 1973). Barnett (1974) found that the requirements of a college major or the precollege mathematical preparation of a student is not the crucial factor for women when making a career choice; rather, women avoid majors in science and engineering because they are men's jobs, not because they require mathematics. The more masculine characteristics a female perceives herself to have the more likely she is to choose a nontraditional career such as science (Baker, 1987). Despite these findings, researchers have afforded little energy to studying the childhood origins of attitudes that may influence career choice in science.

The first category of empirical efforts to measure attitudes toward science included scales that were developed for older children. The Image of Science and Scientists Scale (ISS) (Krajkovich and Smith, 1982) was designed to assess high school students' attitudes toward science. They were interested in the ongoing underrepresentation of women in science careers and in the training processes leading to the careers. Numerous programs such as the Career Oriented Modules to Explore Topics in Science (COMETS) (Smith, Molitor, Nelson and Matthews, 1982), developed and implemented to enhance positive attitudes toward women in science, led to the need for scales to measure attitude change after subjects were exposed to programs. Curriculum materials utilized in the programs were usually designed for grades five through nine, and enabled science teachers to provide students with role models of women in science careers, a technique which had been shown to be a successful avenue for encouraging more girls to consider pursuit of science careers. An instrument was developed based on the 957 summaries originally presented by Margaret Mead and Rhoda Metraux (1957), the results of a nationwide survey that investigated the image of science and scientists as held by secondary school students. In the course of the follow-up study, Krajkovich (1978) was able to use the instrument to compare the results of 1957 to those of 1978. Large group testing on an interview or written narrative basis seemed to be an overwhelming task for one researcher; and the need arose for a validated instrument to measure this particular aspect of the affective domain. Krajkovich was influenced by McLure and Piel (1978) and Smith (1976), who in developing tests for high school seniors and older students, demonstrated the importance of three dimensions of attitude toward women in sceince: *characteristics needed for science career pursuit*; *compatibility of spouse, parent, and career roles*; and *equality of opportunity to pursue a career*. Later, in selecting items for the WiSS, these three categories were used by Erb and Smith (1984) to screen and modify the items initially suggested by Mason (1975) for testing sex-role attitudes. The WiSS, constructed to measure attitudes toward women in science, was administered to early adolescents; significant differences in attitudes of females and males toward women in science were found. The work of Erb and Smith, however, did not identify the origins of variation in the acquisition of the role stereotypes that might eventually constitute obstacles to recruitment to science. Early childhood acquisition of attitudes toward and interest in scientists remains an area where virtually nothing has been investigated, perhaps because it is widely believed that few interventions are effective in changing the conditions of the informal socialization that goes on in the home.

A second category of empirical efforts having implications for the measurement of attitudes toward scientists has been associated with cultural transmission theorists who contend that the acquisition of gender identity is the product of gradual learning (Bandura, 1971, 1973; Bussey & Bandura, 1984). These theorists propound that parents, teachers, and other adults shape a child's behavior by reinforcing responses that are deemed appropriate to the child's gender role and by discouraging inappropriate ones. Cognitive-developmental theorists (also called *labeling theorists*) emphasize that children actively seek to acquire gender identities and roles. Children come to label themselves as *boys* or *girls* when they are between 18 months and 3 years of age (Kohlberg, 1966, 1969; Kohlberg and Ullian, 1973) and once they have identified themselves as males or females, they then want to adopt the behaviors consistent with their newly discovered status. This process, termed *self-socialization*, results in children forming a stereotyped conception of maleness and femaleness, an oversimplified, exaggerated, cartoon-like image revolving about such highly visible traits as hair style, dress, stature, and occupation. They then use their stereotyped images to organize their behavior and to cultivate attitudes and actions associated with being a boy or a girl. Both the cultural transmission and labeling theories of gender-role learning have received research support (Macoby and Jacklin, 1974, Bem, 1975); Weitzman (1972) conducted an investigation of how the sex-role socialization of preschool children is accomplished through the vehicle of picture books; Paludi, Geschke, Smith, and Strayer (1984) have studied preschoolers' knowledge of sex-determined role standards; and Aboud (1988) has studied prejudice in children.

Based then on the predictive leads that, 1) science flourishes pending unqualified reception to talent, 2) practicing scientists emerge from a *scientific talent pool* of students who manifest both positive attitudes (interest) and ability by a specific point in their development, and 3) that an individual's perception of the scientist encourages recruitment to science when the self-perception agrees with his/her perception of the scientist's characteristics; the following null hypothesis was generated.

Ho: Controlling for ability, attitudes toward women in science will be the same among young urban school-age children, despite gender, race/ethnicity, age/grade, socioeconomic status.

Figure 1 about here

Method

Given that inferences for the maintenance of science can be made from tests of the research hypothesis that socialization affects attitudes toward science, the purpose of this investigation was to design a causal comparative (ex post-facto) study to test the relationship between differential socialization (according to ascriptive characteristics such as gender and race), the independent variable, and attitudes toward women in science, the dependent variable. The research was conducted in several parts; first the instrument, developed to measure attitudes, was written, modified after an initial field testing, and administered anonymously; second, tests of reliability and construct validity were carried out.

Subjects

Subjects in the study were 791 children from New York City schools. The sample was selected using a non-probability, purposive technique (Kish, 1965). Teachers from 25 schools in the metropolitan area and who were concurrently enrolled in graduate education courses, elected as a way of earning optional extra credit toward their final course grade, to participate by administering the Early Childhood Women in Science in Scale (ECWiSS) to their students and by providing background information on students in their classes. Of the sample, 362 students (46.1%) were reported to be boys and 424 (53.9%) girls; 69 (8.7%) were reported to be in kindergarten, 112 (14.2%) in first grade, 177 (22.4%) in second grade, 223 (28.2%) in third grade, and 210 (26.5%) in fourth grade. Teacher reports also indicated that 256 (32.7%) of the respondents were black, 200 (25.5%) white, 285 (36.4%) Hispanic, 32 (4.1%) Asian, and 11 (1.4%) were unclassified. Of the 791 subjects, 245 (41.7%) were reported as low ability students, 172 (29.3%) as average ability students, and 170 (29.0%) as high ability students. Data on three dimensions of the socioeconomic status of students was indicated; 498 (72.1%) were eligible for *free lunch*, 193 (27.9%) did not qualify for *free lunch*. Information of the family structure was obtained; 368 (58.0%) children lived with both parents, 267 (42.0%) children lived with either the mother only, or father only, or the mother and other relatives, or the father and other relatives, or just relatives, or some other person. School sector data showed 135 (17.1%) of the students were enrolled in private schools and 654 (82.9%) in public schools.

Measuring the Dependent Variable (Attitude Toward Women in Science)

Using the WiSS as a conceptual template, a list of 27 items was initially constructed to reflect sentiments toward females in scientific roles. Teachers who volunteered to participate in the study were informed that the questionnaires were developed to investigate children's attitudes toward women scientists. They were asked to supply confidential information on the background of children (for whom parental consent was obtained) to assist in determining whether children's attitudes vary by gender, age/grade, race/ethnicity, ability, and socioeconomic status (free-lunch eligibility, family structure, and school sector). Teachers were also given instructions for administration of the non-verbal Likert-type scale, for pre-literate and other early elementary school children. Each of the 27 items was presented orally; response choices were presented pictorially in the form of four line-drawn, neuter and non-racial faces with expressions ranging from a pronounced smile to a pronounced frown (Beere, 1970; Johnson, 1976; Ayers, 1977; Rim, 1977). The *faces* corresponded to the response categories; (1) *strongly disagree*, (2) *disagree*, (3) *mildly disagree*, (4) *mildly agree*, (5) *agree*, and (6) *strongly agree*, as shown in Figure 2.

Figure 2 about here

Students were told to color in the face that expresses how s/he feels about what was stated by the teacher. The neutral choice found in most Likert-scales was omitted to force a judgment. The 27-item instrument was administered to five second graders to test for clarity. To enhance reliability, cartoon characters appearing next to the numbered items were included as markers to help children to identify the statement being read by the administrator. Teachers were further instructed to administer the instrument either under standardized test conditions or in small groups. It was explained that this procedure would lessen threats to *internal validity* by discouraging children from copying their peer's responses. Teachers were asked to have a paraprofessional or other assistant administer the questionnaire, whenever possible so that children would not be inclined to respond in a manner consistent with their teacher's facial expression or demeanor. Teachers were also asked not to explain the definition of the word, *scientist* because the questionnaire was designed to measure the image of the scientist presently held by children. To further foster the reliability of the instrument, respondents who did not understand the meaning of an item were instructed not to enter a response for that item. Students were told there was no penalty for leaving questions unanswered and that there were no *right* or *wrong* answers. Data on the test administration was collected and the items that were causing the most trouble for the students were reworded.

As a result of this administration of the instrument, fifteen of the items were reworded, the scale was changed to a four-point Likert scale (see Figure 2), and eight items constituting a separate career preference scale were added. These eight items, derived from a scale constructed by the developers of COMETS (Smith, Molitor, Nelson and Matthews, 1982) staff was based on the classification of occupations developed by Roe (1976). Roe's scale consists of 49 items and is comprised of science, service, and business subscales. It was developed using the same process as the WiSS. Each item on the scale is a career possibility in some classification (e.g., physician or physical scientist in science; social worker or school counselor in service; and insurance salesperson or buyer in business). Subjects are asked what jobs they would like to try for a day. They can respond on a four-point scale from *no interest* to *high interest*, or they can answer *don't know*. The internal consistency alpha and test-retest reliability *r* of these subscales are moderate and strong, respectively (a = .76 and r = .58 for the science career subscale, a = .59 and r = .65 for service careers, and a = .59 and r= .54 for business careers). A significant positive correlation between students' scores on the WiSS and their scores on the science careers subscales exists, and on the other hand, little or no correlation between students' attitudes concerning women in science and their preference for careers in business or service occurs. The predicted pattern of correlations between the WiSS and five selected scales was observed for both sexes (Erb and Smith, 1984). The eight items, derived from Roe's measures, were appended as a mechanism for intertest correlation. The revised 35-item instrument was then administered. Scores from negatively valued items were reversed and then all items were summed to produce a total scale score. Internal consistency and item-total correlation strategies were employed to cull items from the 27-item domain to represent the general construct of attitude toward women in science. For each item the means, sigma, choice distribution, and correlation with the total scale score were inspected. Those items shown to have a low or negative correlation with the total score ($r \leq .35$) were eliminated from the final form of the ECWiSS. The item scores from one-half of the sample was correlated with the second half. Because these preliminary analyses produced a 27-item measure of attitude toward women in science with high internal consistency, the instrument was further tested for construct validity and aimed at exploring the hypothesized relationship between attitudes toward women in science and the exogenous variables.

The concept, *attitudes toward women in science*, evolved, on face validity, as a descriptor or rubric to describe a syndrome of diverse, yet interdependent behaviors; an instrument that purports to measure attitudes toward women in science. Attitudes should therefore reflect the multidimensionality inherent in the construct originally defined by Mason (1975). Because relying exclusively on an internal consistency strategy tends to ignore the important subcomponents of the construct in favor of aggregating those components into an undifferentiated general construct reflected by a total score, a procedure was proposed that would allow for the examination of the construct as it was best construed.

To examine the internal structure and multidimensionality of the ECWiSS, the protocols of 791 subjects were analyzed using a principal-components analysis in attempt to produce evidence for a general component of attitudes toward women in science as well as evidence for roughly the three interrelated components first introduced by Mason (1975) and later reintroduced by McLure and Piel (1978), Smith (1976) and Erb and Smith (1984). Using the general expression (equation) for the estimate of the *j*th factor F_j (the W_i's are factor score coefficients, and *p* is the number of variables)(Norusis, 1985)

$$F_j = \sum_{i=1}^{p} W_{ji}X_i = W_{j1}\,X_1 + E_{j2}X_2 + \ldots + W_{jp}X_p$$

evidence for a general component of attitudes toward women in science was satisfied by meeting the following methodological criteria: (a) the interitem correlation matrix exhibits no significant negative correlations; (b) the first unrotated component has an eigenvalue that is substantially greater than the eigenvalue of the next largest component; (c) all of the items show positive nontrivial loadings on the first unrotated principal component; (d) the rotated component pattern shows no substantial negative loadings; (e) the intercomponent correlation matrix exhibits no significant negative correlations, and each component is positively correlated with two or more of the other components; and, (f) a principal-components analysis of the first-order component intercorrelation matrix produces a higher order first unrotated component that accounts for a substantial proportion of the intercomponent variance, and all of the components show non-trivial positive loadings on the higher order first unrotated component.

Measuring the Independent Variables (Gender, Age/Grade, Race/Ethnicity, Ability, Socioeconomic Status) and their Effects

The second phase of this research employed a causal comparative design, to measure the construct validity of the general measure of attitude toward women in science and to test the hypothesis generated. The logic of an *ex post facto* (Smith and Glass, 1987) strategy is the researcher starts with the effect and works backward — in this case, attitudes already exist. Analysis of variance (ANOVA) was performed to test for significant differences in attitudes according to gender, race/ethnicity, age/grade, and socioeconomic status (with ability controlled).

As a caution against misinterpretation of *statistically significant* results, hierarchical linear regression analyses were performed to estimate the size of the actual effect or the *practical significance* of the research. Cohen (1977) refers to the actual effect (estimated by the sample statistic) as the concept of statistical power. For example, the percent of the variance of the dependent variable that is explained by differences in the independent variable can be calculated as a way to judge the outcome of the study (Smith and Glass, 1987). The additional variance in attitude that can be accounted for by one predictor (e.g., age/grade) above and beyond that explained by variables entered previously (e.g., gender) was obtained by computing the change in R_2 when the last variable was entered. The concept, *socialization* (ascription-based), was operationalized as several independent variables: *gender* was coded as (1) *male* and (0) *female*; *age/grade* was coded as (1) *kindergarten*, (2) *first grade*, (3) *second grade*, (4) *third grade*, (5) *fourth grade*; *race/ethnicity* was coded as (1) *black*, (2) *white*, (3) *Hispanic*, (4) *Asian*, and (5) other; *ability* was coded as (1) *low score on latest standardized reading test* (at or below 50th percentile), (2) *average-score on latest standardized reading test* (between 50th to 75th percentile, (3) *high score on standardized reading test* (at or above 75th percentile; (teacher estimated performance for children in kindergarten and first grades since standardized tests are mandated for second grade students); *socioeconomic status* had three dimensions and was coded as (a) *free lunch* (1) *student receives free lunch*, (2) *student does not receive free lunch* (eligibility for free lunch is based on a questionnaire filled out by the parent/guardian of each child, which asks respondents to report their annual income [NYC Board of Education, 1988]).; (b) *household structure* was coded as (1) *in-tact with both parents in home*, (2) *both parents not in home*; (c) *school sector* was coded as (1) *public*, (2) *private*; (*gender of test administrator* was coded as (1) *male*, (0) *female*, but this information was not used in the analysis). Variables with more than two attributes were recoded into dummy variables (having values of 0 and1 for the purpose of the regression analyses [Kerlinger, F. and Pedhazur, E, 1973]).

Results

Reliability

Two reliability models were used in this investigation — the alpha model and the split model. In the first series of analyses, the response characteristics of the 27 ECWiSS items were examined to determine whether each of the items was behaving in a monotonic manner in relation to the full-scale ECWiSS score. The alpha model computed Cronbach's alpha and standardized item alpha

(Cronbach, 1951). The coefficient alpha estimate of reliabiity equaled .90 and the standardized item alpha equaled .90. The split model (Guttman, 1945) partitioned the variables in the scale into two subsets. The sum was computed for each subset and the reliability calculations made use of only the information contained in the two sums for each case. The Guttman split-half reliability coefficient indicated a strong positive correspondence (.87; the alpha for part 1 (first 14 items) was .84, and the alpha for part 2 (13 items) was .81). The 27 items on the ECWiSS along with their positive or negative values and correlations with the total scale score are displayed in Table 1.

Table 1 about here

Validity

The construct validity of the ECWiSS was established using procedures described by Cronbach and Meehl (1967) as known groups and correlates. Second, a principle-components analysis was performed.

Known Groups.

Construct validity and the ***universalism*** hypothesis were analyzed using the known groups procedure. A factorial design requiring analysis of variance (ANOVA) was employed to test the capacity of the ECWiSS to discriminate differences between groups. The null hypothesis that the mean score on attitude toward women in science would be the same between independent variables and across all attributes (groups) of gender, race/ethnicity, age/grade, socioeconomic status (free lunch eligibility, household structure, and school sector), with ability controlled, was tested. Two-, and three-factor ANOVAs were performed to determine the effects of two or more factors simultaneously as an empirical basis for generalizing the main effects of any factor across all levels of the other.

The results of the analyses of variance appear in Tables 2, 3, and 4. "Talent being equal, how much does attitude vary according to ascriptive characteristics?". Respondents, overall, mildly disapproved of women being scientists (which was reflected by a grand mean score of 2.87 with a standard deviation of .58; the mean scores and standard deviations for low, average, and high ability students, respectively, were 2.71, .63; 2.89, .50; 3.04, .52). The null hypothesis was rejected based on evidence of differences in the scale scores across attributes of the independent variables, with ability as a covariate. A mean difference in attitude was found for gender with males significantly less in agreement with women doing scientific work than females [$F(2,496)=56.01$; $p \leq .001$]. Significant age/grade differences in attitude were also found, with younger children, on the average, reporting more negative feelings about women in science than older children [$F(5,497)=18.74$; $p \leq .001$]. Differences in means were consistently greater between the youngest children and progressively older children, with the largest mean difference between children in kindergarten and children in the fourth grade. The ECWiSS also discriminated significant differences in attitude for children from varying socioeconomic strata with the more well-to-do showing more agreement with women in science than the less well-to-do [$F(2,462)=18.90$; $p \leq .001$]. Main effects were found for household structure and school sector, variables which also reflect aspects of socioeconomic strata. Children living in homes with both parents present had a significantly more positive attitude to women in science than children living in homes that were not intact [$F(2,403)=8.62$; $p \leq .001$] and students attending private school were, in general, significantly more in agreement with women being scientists than students enrolled in public schools [$F(2,497)=30.28$; $p \leq .001$].

Main effects found for gender with each of the other variables were qualified by a number of interactions. Main effects were found for gender with each of the other variables. From the analysis of gender and race/ethnicity (with ability as a covariate), a significant main race/ethnicity effect appeared with the mean score on attitude reliably, but only slightly greater (according to [Scheffé, 1959] post hoc comparisons) for whites than for blacks, Hispanics and Asians, respectively [$F(4,496)=2.05$; $p \leq 1.0$] and when this effect was qualified for gender, no interactive effects were detected. A somewhat modest interactive effect was found between gender and age/grade with males in kindergarten and first grades reporting less agreeable responses to women in science than second and third grade females [$F(4,486)=3.59$; $p \leq .05$]. Females with high ability were reliably, but only slightly more positive in attitude than males with low ability [*F*(2,491)=2.83; $p \leq 1.0$] indicating the relative independence of attitude toward women in science from talent. The average scores on attitude for males and females was essentially the same across all categories of socioeconomic status, but a significant and substantial interactive effect was found between gender and school sector with the differences in mean scores on attitude being more positive for private school than for public school students [*F*(1,492)=37.95; $p \leq .001$] (the mean being highest for private school females).

Tables 2, 3, and 4 about here

Besides these lower level findings, to further qualify the generalization of the effects of ascription on attitudes toward women in science, are the findings from the three-way analyses of variance. Figure 3 depicts the only reliable three-way analysis of variance. For gender, race/ethnicity, and socioeconomic status, the mean difference in attitude toward women in science between males and females was significantly greatest for the white *poor* [*F*(4,461)=3.41; $p \leq .05$] with lower SES white males manifesting the most disagreement with women in scientific fields as contrasted to higher SES white females. For Hispanics, differences in gender effects were the least for high SES students.

Regression Analyses

The results of the stepwise linear regression analyses, used to test the *actual* effects of the independent variables on attitude toward women in science are reported in Table 5.

Table 5 about here

Using the stepwise procedure (SPSS^x, 1986), hierarchical regression analyses were used to assess the additional variance in attitude toward women in science that can be accounted for by a predictor above and beyond that explained by variables entered previously. The change in R^2 was computed when the last variable was entered. First, scores on the ECWiSS were regressed on ability; then gender, race/ethnicity, age/grade/, socioeconomic status, household structure, and school sector were entered into the equation. The coefficients are the standardized regression coefficients (ß) that control for the effects of the other variables in the regression equation. Significant ($p \leq .05$) increments appeared in the explained variance with changes in R^2 (.20) found (with ability controlled [.03]), for gender (.11), school sector (.02), and age/grade (.01); gender explained the greatest proportion of the variance in attitudes toward women in science.

Intertest Correlation.

According to Cronbach and Meehl (1967), a second method for testing the construct validity of an instrument is to correlate the new test with measures of similar constructs. If significant positive correlations are observed, those observations are evidence for the construct validity of the new scale; conversely, a nonsignificant or negative correlation with a measure of an unrelated or dissimilar construct also supports construct validity. The predicted pattern of correlation coefficients was shown to exist empirically; thus evidence to support the construct validity of the new scale was produced. The scores on the ECWiSS were correlated with two other measure — the *occupational inventory* and an *observational perspective rating*.

Scores on the occupational inventory and ratings of the teacher's estimate of the student's attitude toward women in science (using the same four-point scale appearing in the ECWiSS) were obtained. The prediction that students with high positive attitude toward women in science would display a positive attitude toward scientists or the discipline of science, was supported. Significant positive and moderate correlations between students scores on the ECWiSS and their scores on the occupational inventory were found. For the occupational inventory, the internal consistency alpha was .39 and the Pearson $r = 0.50$ ($p \leq .05$), reflected the association between the two sets of scale scores. The test of the association between the teacher's estimate of the student's image of the scientist and the student's score on the ECWiSS resulted in a positive and moderate correlation ($r =$ .51

Principal-Components Analysis

The results of the principal components analysis provided evidence for a general component of attitudes toward women in science and several interrelated components.

Table 6 about here

A good factor solution was found which was both simple and interpretable; the relationships amongst variables were represented parsimoniously and the factors were meaningful. Having used a principal-components analyses with an oblique rotation procedure on the ECWiSS protocols of 791 students, five ECWiSS components were identified. Of the various solutions tried, the one that best met our criteria was a five-factor solution that accounted for 49% of the total ECWiSS variance, and the first component accounting for 29% of the total ECWiSS variance. The following are the relevant features: the observed interitem correlation matrix contained no significant negative correlations, with the largest being -.0003. The eigenvalue (lamda) of the first unrotated principal component (lamda = 7.40) was over three times greater than the eigenvalue of the next largest component (lamda = 2.38). All of the ECWiSS items showed positive loadings on the first unrotated principal component, with no loadings shown that were below .34. The rotated component pattern showed few negative loadings with one loading shown at -.14 and a few not greater than -.05. The average calculated item communality for the 27 items was .52. Each of the five components had a minimum of 4 marker items that unequivocally loaded at .51 or greater on that component. The variance component associated with each rotated component exceeded a value of 2.0. Finally, the largest negative correlation in the intercomponent correlation matrix was a trivial -.04 whereas the average intercomponent correlation was .22. Furthermore, each of the five components showed a correlation of .20 and above with at least two other components. On the basis of the marker item (an item which univocally loads on a component at .50 or higher) content (and consistent with the dimensions conceptualized on face validity as used in the work of Erb and Smith (1984), the three ECWiSS components were named *role specific self-concept*, *home-related sex-role conflict, and work-related sex-role conflict.* Table 5 shows the component structure. These items represent the best measure of the general construct of attitudes toward women in science and its components. The scale loadings on the first unrotated principal component were .78, .70, .69, and .58, indicating clearly that a general factor is reflected in the five ECWiSS components.

Discussion

In a *Letter of Transmittal* (Schmitt, 1987), the Chairman of the National Science Board of the National Science Foundation communicated that the actions of Government and industry in recent years demonstrates their recognition of the critical contributions of basic research and advanced technology development to our health welfare, economic competitiveness, and national security. Out of concerns for the maintenance of American science, both conventional and theoretical explanations have been set forth for the failure of various segments of the population to be equally represented in this seemingly valued enterprise. The theoretical posture that science must be open to talent to be ongoing, is known as *universalism in science*. This investigation, has been intended as an observation of the relationship between socialization and membership in the science talent pool — the effects of gender, race/ethnicity, age/grade, socioeconomic status, and ability on the attitudes of young children toward women in science. Inferences for the theory that competence, not ascription lead to the sustenance of science have been made.

On the average, the attitudes of young children toward women in science are neither positive nor negative, with a small tendency to be negative, and differences in socialization are only slightly associated with variations in attitude. Regardless of talent, children's attitude toward women in science varies according to whether they are boys or girls, relatively younger or older, middle-class- or working-class, or attending public or private school. The main effect of gender remains consistent across all categories of race/ethnicity, age/grade, and socioeconomic factors. This lower order finding is further qualified in that the more able, older females from higher socioeconomic strata, manifest the most agreement with women as scientists, and white males from poor homes show the least approval of women scientists. Clearly, as Freud wrote in a letter to his fiancée, '...human beings consist of men and women and . . . this distinction is the most significant one that exists ' (Wollheim, 1975). We can infer from this special case that *universalism* is a necessary and sufficient cause for the operation of science. Based on the norm of ***universalism***, it was expected that ascriptive factors, as opposed to talent, get in the way of the optimal functioning of science, and it was found that differences in attitude toward women in science are, in fact, explained by reasons other than competence. The nature of the evidence that leads to this conclusion is described in more detail below.

In the initial phase of the research, the credibility of the measure, attitude toward women in science, was assessed by the Early Childhood Women in Science Scale (ECWiSS). The ECWiSS is both a reliable and valid measure of the construct — attitude toward women in science — as it occurs among young children. It has been shown to be a reliable instrument whether measured by estimates of internal consistency (alpha = .90) or split-half reliability ($r = .89$). Its validity has been established first, by showing that the ECWiSS clearly distinguishes between scores of young children according to gender, age/grade, race/ethnicity, socioeconomic status, and ability, on the construct of interest.

The relative contribution of ascriptive characteristics to interest in science is profoundly illustrated by the first and most pervasive finding. The hypothesis that, holding ability constant, the contribution of ascriptive characteristics to attitude toward women in science will be equal between variables and across all attributes, was rejected. It was found that males more than females, regardless of ability, disagree with women being scientists. (These findings replicate those of Smith and Erb, 1986). Retaining the image of the traditional female appears more important for boys than for girls and confirms claims, such as Baker's (1987), that women avoid science and men think women should avoid science, not because it requires skill in math, but because science is a man's work. The primary role of women is to serve as status symbols (Veblen, 1899) for men. For example, men typically groom themselves for work by retaining short hair and short nails, and by wearing slacks and low-heeled shoes, whereas women prepare themselves to be glamorous objects who display colored polish on long nails or who wear uncomfortable high-heeled shoes. This finding is indicative of a *socio-structural* obstacle to the formation of positive attitude toward women in science and has implication for the redefinition of traditional gender roles. Positive attitude toward women in science depends upon equitable standards of behavior that allow men and women to express a broad range of human emotions and role options. This finding also suggests that ongoing research on the compatibility of gender-identity with the image of the scientist include attention to the changing image of science. Recent controversies over the normative structure of science, or over whether an *ethos* or adherence to core values is a prerequisite for production of scientific knowledge (Toren, 1983) affect the image of science. Toren claims, for instance, that the distinction made between academic and industrial science is regarded as an attempt to protect exclusivity and to define away categories of scientists because they do not fit into a preconceived picture of science. Or, she argues that the belief in the rationality and objectivity of science is viewed by some as an ideology which serves the interests of the political-industrial establishment by distorting public perceptions of the causes and consequences of scientific knowledge. Duschl (1988) discusses how views of science as either positivistic or as relativistic, influence children's perceptions of science. Science as *rigid* (objective) in its evaluation of evidence rather than *arbitrary* (intersubjective), and *disinterested* in its definition of problem choice, makes it more compatible with male gender stereotypical behavior

Surprisingly, the hypothesis was not rejected in the case of race/ethnicity, the second ascriptive characteristic examined. Occupational role stereotypes are cross-culturally, located along the lines of gender boundaries rather than race/ethnicity boundaries, so that race/ethnicity, by itself, does not discriminate difference in attitudes toward women in science. When the two factors of gender and race/ethnicity are considered in combination rather than separately, the observable effects are over and above the magnitiude of the effects observed independently, so that while overall, no significant effects were detected for race/ethnicity, a reliable finding between gender and race/ethnicity was found. Amongst black, white, hispanic, and Asian children, the difference in attitude toward women in science was greatest for white girls and boys. Attitudes were also found to vary reliably, according to age/grade. Very young children are more likely, than progressively older children, to disagree with women doing scientific work This finding is interpreted to mean that age could be a barrier to the formation of agreeable attitudes toward women in scientific work.

The developmental constraints which determine how children internalize roles (Kohlberg and Ullian, 1973) are not necessarily detrimental to the formation of positive attitudes to females in non-traditional occupations such as science, but if the *rigid* images of role models, characteristic of young children (Fagot, Leinbach, and Hagan, 1976), are gender stereotypical then age/grade becomes an ascriptive deterrent to the formation of positive attitudes.

Besides gender and race/ethnicity, and age/grade, attitude toward females in scientific roles varies according to socioeconomic status as it concerns household income, number of parents in the home and public or private schooling. Higher household income and private schooling are more frequently associated with positive attitude toward women in science than lower household income and public schooling. The well-to-do white females from private schools show the most agreement to women in scientific roles. This empirical observation might be explained by the view that the middle-class experience enough leisure to be liberal (Veblen, 1899), or by Melvin Kohn's (1959) insights that working-class parents are more concerned about their children conforming to the expectations of others while middle-class parents emphasize that their children be self-expressive.

The higher order analyses conducted to further qualify the generalization of gender effects on attitude toward women in science revealed that while ascription has the most pervasive effect for gender, this generalization requires the following qualification: in terms of attitudes toward women in science, race only matters when one is male and poor. The low-income white male relies most heavily on gender stereotypical behavior. Traditional females are extremely important for this group relative to any other group, perhaps because of fewer options afforded for shaping male identity; reliance on females for nurturance and affirmation is inevitably an outcome. It is easier for poor women than for poor men to marry *up* (Chodorow, 1974), and wishing greater status attainment for women is, for the poor white male, a mechanism for limiting the choice of a mate. For black males, the Veblen depiction is less important; black male identity has typically been formed in light of black females assuming non-traditional roles as single heads of households. Hispanic children have also found it less difficult to negotiate their view of female roles.

The present study examined the extent to which ascriptive-based socialization according to gender, race/ethnicity, age/grade, socioeconomic status, predicts attitude toward women in science as measured by the multi-dimensional ECWiSS. Acriptive variables explained about 16 percent of the variance in attitudes beyond that explained by ability (with gender explaining the greatest amount of the variance). The salience of this finding is for the identification of more gender-related predictors of attitude toward women in science.

The results of the principal-components analysis conducted to test the validity of the dimensions defined in the ECWiSS, constitute a measure of the stability of the three-dimensional characteristics of the original WiSS, and find explanation in the research of Baker (1987) on the influence of role-specific self-concept and sex role identity on career choices in science. *Role-specific self concept* is the perception individuals have of their competency when engaged in a particular task. *Sex roles conflict* is the feeling individuals have when they are engaged in activities they believe to be inappropriate for their sex. The first factor in the principal-components analysis explained 29% of the variance in attitudes, which means the attitude of very young children toward women in science is greatly affected by how they see themselves in relation to their image of the scientist. Approximately 13 percent of the variance was explained by the second factor, the degree to which children felt the characteristics of the female scientist match what they believe is typical for males and for females. These findings suggest that the child's image of the female scientist is in line with the stereotypes portrayed by Rousseau (1979), who believed that rationalism and egalitarianism would tend to destroy the sexual differences just as they were leveling class and national distinctions; marriage and the family would decay and the sexes be assimilated. He argued that there can be no natural, whole, social man if women are essentially the same as men and that the two sexes are different, each sex requiring the other in order to be a whole being, or together forming a single whole being. A woman therefore naturally cares for her children; "thus a man, loving her exclusively, will also care for the children." To cultivate man's qualities in women and to neglect those which are proper to them was to Rousseau, to work to their detriment. "Little girls love adornment almost from birth." For man, he asserted, the aim is the development of strength;

for woman it is the development of attractiveness; women need enough strength to do everything they do "with grace;" men need enough adroitness to do everything they do with facility. "In fact, almost all little girls learn to read and write with repugnance. But as for holding a needle, that they always learn gladly." Rousseau believed dependence to be a condition natural to women and thus girls feel themselves made to obey. He also asserted that from habitual constraint comes a docility which women need all their lives, since they never cease to be subjected either to a man or to the judgments of men and they are never permitted to put themselves above these judgments."

For an instrument that better reflects the complexities inherent in the attitude toward women in science construct, modification and extension of the present work is required. The first recommendation is for refinement of the scale by eliminating the items that show weaker factor loadings. Second, the findings indicate that about 50 percent of the variation in attitude is explained by gender role behavior, but the residual 50 percent of the variance remains unexplained. Examination of the construct of attitude in terms of other dimensions of gender-compatible images is required. Previous research on the pre-school child's knowledge of sex-determined role standards identifies *physical aggression*, *competitiveness*, *excellence in motor ability*, and *independence* as male stereotypical behavior (Paludi, Geschke, Smith, and Strayer, 1984). Questions pertaining to the uses of science may tap these aspects of attitude toward female scientists. Carefuly conducted qualitative work, such as field-interviews coupled with open-ended self-report surveys will aid in retooling the conceptualization of the ECWiSS.

In sum, how does this constellation of findings help us to understand, more generally, the normative structure of science as it pertains to recruitment to scientific careers? The *universalism* notion that science operates to the degree it is open to talent is not tenable (statistically) in this case but, it was found that only a small amount of variation in attitudes toward women in science can be attributed to ascriptive factors, with gender accounting for most of the differences. The consequences of this major finding that, regardless of ability, males, more than females, disapprove of women becoming scientists, appear mildly dysfunctional for the maintenance of American science, especially if we assume that early learning sets limits for future socialization patterns. Although the relationship between male and female attitudes toward women in science is not complimentary; in other words, girls do not accept the image of women scientists to the degree that boys reject it, male disagreement with women in science threatens the functioning of science. For example, girls who, at some point in the developmental sequence, are both willing and able to be scientists may be thwarted in realizing their goal if men do not accept females in these roles. As Hewlett (1986) argues, because society sees women as being unable to balance the dual responsibilities of motherhood and work, they are likely to retain their second-class citizenship. Further evidence which shows the facility with which women can reconcile the demands of childbirth and childrearing with those of earning a living will reflect the promise that changes in gender stereotypes hold. The work of Cole and Zuckerman (1987) is exemplary. They found that female scientists who marry and have children are no less productive than single female scientists. The results of this study furthermore suggest that differences in productivity between males and females might be accounted for by some other type of gender discrimination. Future investigations in this vain mitigate against stereotypes which perpetuate sex-role conflict and negative attitude toward females having scientific careers.

An additional implication of the findings of the present study, is in terms of what Lavin (1976) has referred to as the *cumulative impact of disadvantage. Minority* students are subject, long before graduation from high school, to an unequal appropriation of the resources foundational to the development of interest and ability in science. Differences that appear very early become reinforced (Eiduson and Beckman 1973). While the chronological distance of early childhood to the phases of maturity at which careers are chosen, makes a correlation seem spurious, this limitation should not preclude further examination of very early socialization processes. To strengthen the predictive capability of the ECWiSS, longitudinal (panel) studies of young children through ninth grade would reveal whether change in attitude toward women in science occurs. If little change is evident, then the dysfunctional consequences of early gender-role socialization for the maintenance of science in society are greater than we presently imagine. Ongoing research focusing on influences which mediate the effect of ascription on interest in science will delineate with greater clarity, the role of *universalism* in the maintenance of science in society. Margaret Mead, commenting on the impact of ascription (1935) stated

> ...Among the Mundugumor people of New Guinea children born with the umbilical cord wound around their necks are singled out as of native and indisputable right artists. Here is a culture . . . that has arbitrarily associated . . . two completely unrelated points: manner of birth and an ability to paint intricate designs upon pieces of bark. . .So firmly is this association insisted upon that only those who are so born can paint good pictures, while the man born without a strangulating cord labours humble and unarrogant, and never attains any virtuosity. . . We see the strength that lies in such irrelevant association once they are firmly embedded in the culture.

References

Aboud, F. 1988. *Children and Prejudice*. New York: Basil Blackwell.

American Psychological Association. 1988. *American Psychologist*. 43:221.

Ayers, J. 1977. "How I feel About Television in School." *Test Collection*. Princeton, NJ: Educational Testing Service.

Baker, D. 1987. "The Influence of Role-specific Self-concept and Sex-role Identity on Career Choices in Science." *Journal of Research in Science Teaching*. 24:739-756.

Bandura, A. 1971. *Psychological Modeling: Conflicting Theories*. Chicago: Aldine-Atherton.

Bandura, A. 1973. Aggression: *A Social Learning Analysis*. Englewood Cliffs, NJ: Prentice-Hall.

Barber, B. 1952. *Science and the Social Order*. New York: The Free Press.

Barnett, R. 1974. "Sex Differences and Age Trends in Occupational Reference and Occupational Prestige." *Journal of Counseling Psychology*. 22:35-38.

Beere, C. 1970. "Group Instrument to Measure Young Children's Attitudes Toward School." *Test Collection*. Princeton, NJ: Educational Testing Service.

Bem, S. 1985. "Androgeny and Gender Schema Theory: A Concceptual and Empirical Integration." *Nebraska Symposiyum on Motivation*. 32:179-226.

Berryman, S. 1983. *Who will do science? Trends and their causes in Minority and Female Representation among holders of advanced degrees in science and mathematics*. New York: The Rockefeller Foundation.

Bills, D. 1988. "Educational Credentials and Promotions: Does Schooling Do More than Get You in the Door?" *Sociology of Education*.. 61:52-60.

Bussey, K. and Bandura, A. 1984. "Influence of Gender Constancy and Social Power on Sex-linked Modeling." *Journal of Personality and Social Psychology*. 47:1292-1302.

Chodorow, N. 1974. "Family Structure and Feminine Personality." P. 47 in *Woman, Culture and Society*, edited by M.Z. Rosaldo and L. Lamphere. Stanford: Stanford University Press.

Cohen, J. 1977. *Statistical Power Analysis for the Behavioral Sciences*. New York: Academic Press.

Cole S. and Cole, J. 1973. *Social Stratification in Science*. Chicago: University of Chicago.

Cole, J. and Zuckerman, H. 1987. "Marriage, Motherhood and Research Performance in Science." *Scientific American*. 256:119-125.

Crane, D. 1972. *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: University of Chicago Press.

Cronbach, L. 1951. "Coefficient Alpha and the Internal Structure of Tests." *Psychometrika*. 16:297-334.

Cronbach, L. and Meehl, P. 1955. "Construct Validity in Psychological Tests." *Psychological Bulletin*. 52:281-302.

Duschl, R. 1988. "Abandoning the Scientistic Legacy of Science Education." *Science Education*. 72:51.62.

Eiduson, B. and Beckman, L. (Eds.). 1973. *Science as a Career Choice: Theoretical and Empirical Studies*. New York: Russell Sage Foundation.

Fagot, B., Leinbach, M., and Hagan, R. 1986. "Gender Labeling and the Adoption of Sex-typed Behaviors." *Developmental Psychology*. 22:440-443.

Guttman, L. 1945. "A Basis for Analyzing Test-retest Reliability." *Psychometrika*. 10:255-282.

Hewlett, S. 1986. *A Lesser life: The Myth of Women's Li beration in America*. New York: William Morrow & Company.

Jencks, C., et al. 1971. *Inequality: A Reassessment of the Effects of Family and Schooling in America*. New York: Basic Books.

Johnson, O. 1976. *Tests and Measurements in Child Development: Handbook II*. San Francisco: Jossey-Bass Publishers.

Kish, L. 1965. *Survey Sampling*. New York: John Wiley & Sons, Inc.

Kohlberg, L. 1966. "A Cognitive-developmental Analysis of Children's Sex-role Concepts and Attitudes." In *The Development of Sex Differences*, edited by Eleanor E. Macoby. Stanford, CA: Stanford University Press.

Kohlberg, L. 1969. "Stage and Sequence: The Cognitive-developmental Approach to Socialization." In *Handbook of Socialization Theory and Research*, edited by D.A. Goslin. Chicago: Rand McNally.

Kohlberg, L. and Ullian, D. 1974. "Stages in the Development of Psychosexual Concepts and Attitudes." In *Sex Differences in Behavior*, edited by R.C. Friedman, R.N. Richart, and R.L. Vande Wiele. New York: John Wiley & Sons, Inc.

Kohn, M.L. 1959. "Social Class and Parental Values." *American Journal of Sociology*. 64:337-351.

Krajkovich, J. 1978. "The Development of a Science Attitude Instrument and an Examination of the Relationships among Science Attitude, Field Dependence-independence and Science Achievement" (Doctoral dissertation, Rutgers University, 1978). *Dissertation Abstracts International*. 39:5A. (University Microfilms No. 78-2038).

Krajkovich, J. and Smith, J. 1982. "The Development of the Image of Science and Scientists Scale." *Journal of Research in Science Teaching*. 19:19-44.

Lantz, A., West, A., and Elliott, L. 1976. *An Impact Analysis of Sponsored Projects to Increase the Participation of Women in Careers in Science and Technology*. Washington, D.C.: National Science Foundation.

Lavin, D. 1979. "Open Admissions and Equal Access: A Study of Ethnic Groups in the City University of New York." *Harvard Educational Review*. 49:53-92.

Macoby, E. and Jacklin, C. 1974. *The Psychology of Sex Differences*. Stanford, CA: Stanford University Press.

Mason, K. 1975. *Sex-role Attitude Items and Scales from U.S. Sample Surveys*. Rockville, MD: National Institute of Mental Health.

McLure, G. and Piel, E. 1978. "College-bound Girls and Science Careers: Perceptions of Barriers and Facilitating Factors." *Journal of Vocational Behavior*. 2:172-183.

Mead, M. 1935. *Sex and Temperament in Three Primitive Societies*. New York: William Morrow & Co.

Mead, M. and Metraux, R. 1957. "Image of the Scientist among High School Students." *Science*. 126:385-390.

Merton, R.K. 1942. "Science and Technology in a Democratic Social Order." *J. Legal Polit. Sociol*. 1:115-126.

_______. 1973. *The Sociology of Science: Theoretical and Empirical Investigations*. New York: The Free Press.

Mill, J.S. 1975. P. xxv in *Three Essays on Liberty: On Liberty, Representative Government, and the Subjection of Women* , edited by R. Wollheim. New York: Oxford University Press.

New York City Board of Education. 1988. Office of Student Information Services (OSIS), 110 Livingston St., Brooklyn, NY 11201.

Norusis, M. 1985. *SPSS^x Advanced Statistics Guide*. Chicago, IL: McGraw-Hill Book Company.

Paludi, M.A., Geschke, Smith, M, and Strayer, L.A. 1984. "The Development of a Measure of Preschoolers' Knowledge of Sex-determined Role Standards." *Child Study Journal*.. 14:171-183.

Post-Kammer, P. and Smith, P.L. 1986. "Sex Differences in Math and Science Career Self-efficacy among Disadvantaged Students." *Journal of Vocational Behavior*. 29:89-101.

National Science Foundation. 1984. *Women and Minorities in Science and Engineering*. Washington, D.C.: National Science Foundation.

__________. 1986. *Women and Minorities in Science and Engineering*. Washington, D.C.: National Science Foundation.

Rim, E. 1977. "Faces Attitude Inventory: Form M." *Test Collection*. Princeton, NJ: Educational Testing Service.

Roe, A. 1976. *Classification of Occupations by Group and Level*.. Bensonville, IL: Scholastic Testing Service.

Rousseau, J. 1979. *Emile or on Education*. (Translated by Allan Bloom.). New York: Basic Books, Inc.

Schmitt, R. 1987. "Letter of Transmittal." *Science and Engineering Indicators*. Washington, D.C.: National Science Foundation.

Scheffé, H. 1959. *The Analysis of Variance*. New York: John Wiley & Sons, Inc.

Smith, W.S. 1976. *Science Education in the Affective Domain: The Effect of a Self-awareness Treatment on Career Choice of Talented High School W omen*.. ERIC Document Reproduction Service. No. ED 128168.

Smith, W. and Erb, T. 1986. "Effect of Women Science Career Role Models on Early Adolescents' Attitudes Toward Scientists and Women in Science." *Journal of Research in Science Teaching*. 23:667-676.

Smith, M. and Glass, G. 1987. *Research and Evaluation in Education and the Social Sciences*. Englewood Cliffs, NJ: Prentice Hall Publishers.

Smith, W.S., Molitor, I., Nelson, B.and Matthews, C. 1982. *Career Oriented Modules to Explore Topics in Science (COMETS)*. Lawrence, KS: Department of Curriculum and Instruction, University of Kansas.

SPSS, Inc. 1986. *SPSS^x User's Guide*. Chicago, Illinois: SPSS, Inc.

Storer, N. 1966. *The Social System of Science*. New York: Holt, Rinehart & Winston.

Toren, N. 1983. "The Scientific Ethos Debate: A Meta-theoretical View." *Soc. Sci. Med.* 17:1665-1672.

Veblen, T. 1899. *The Theory of the Leisure Class*. New York: The Viking Press.

Vetter, B. 1986. "The Last Two Decades." *Science*. 7:62-63.

Weitzman, L.J., Eifler, D., Hokada, E., & Ross, C. (1972). Sex-role socialization in picture books for preschool children. *American Journal of Sociology, 77(6)*,1125-1150.

Table 1

Item-Total Correlations for the Full-Scale Early Childhood Women in Science Scale (ECWiSS)[*]

Item-Total Correlation	Direction of Scale[**]	Numbered Scale Item
DIMENSION 1: WOMEN POSSESS CHARACTERIISTICS WHICH ENABLE THEM TO BE SUCCESSFUL IN SCIENCE CAREERS.		
.57	+	1. Women can be as good in science careers as men can. *1. Women can be good scientists just as men can be.*
.60	-	2. Men are more qualified to become scientists. *2. Boys have more of what it takes to become a scientist.*
.38	-	3. Careers are good for women as long as they are not the boss. *3. It is good for a woman to have a job as long as she is not the boss.*
.56	-	4. Women scientists are weird. *4. Women scientists are weird.*
.58	+	5. Women can make important scientific discoveries. *5. Girls can do important work in science.*
.46	+	6. Scientific research can be done equally well by men and women. *6. Work in science can be done just as well by men as by women.*
.53	-	7. Women are not reliable enough to hold top positions in scientific and technical fields. *7. Women can't be counted on enough so they shouldn't have the most important jobs in science.*
.58	+	8. Both men and women can be equally good in science and math. *8. Girls can be as good as boys in science and math.*
DIMENSION 2: WOMEN'S ROLES AS MOTHER AND WIFE ARE COMPATIBLE WITH SUCCESSFUL SCIENCE CAREER PURSUITS.		
.52	-	9. A husband's success in his career is more important than a wife's success in her career. *9. For a daddy to do well in his job is more important than for a mommy to do well in her job.*
.37	-	10. A woman's basic responsibility is raising children. *10. The most important job a mommy can have is taking care of her children.*
.43	-	11. A woman with a science career will have an unhappy marriage. *11. A lady scientist will not get along with her husband most of the time.*
.39	+	12. Both men and women can combine careers with family life. *12. Both men and women can go to work and have families too.*
.48	-	13. A wife should spend more effort to help her husband's career than she spends on her own. *13. A mommy should work harder to help a daddy with his job than on her own job.*

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[*] Italicized ECWiSS items are revised WiSS (Erb and Smith, 1984) items.

[**] To avoid response bias, the scale direction was alternated so that items reflected *positive* /agreeable (+) or *negative* /disagreeable (-) attitudes toward women in science.

Item-Total Correlation	Direction of Scale	Numbered Scale Item
.39	-	14. Getting married is the most important thing in a woman's life. *14. Getting married should be the most important thing in a woman's life.*
.49	+	15. A woman should be considered for a job based on her qualifications regardless of whether she is married and has a family. *15. A woman should be able to get a job even when she is married and has children.*
.34	-	16. For a woman it is more important to be a successful wife and mother than it is to be successful in a career. *16. For a woman it is more important to be a good wife and mommy than to be good at her job.*
.52	+	17. Women can combine successful careers with successful marriages. *17. A woman can be good at her job and be a god wife too.*
DIMENSION 3: WOMEN AND MEN OUGHT TO HAVE EQUAL OPPORTUNITIES TO PREPARE FOR AND PURSUE SCIENCE CAREERS.		
.54	+	18. A woman should have the same job opportunities in science careers as a man. *18. A woman should be able to get the same kind of job as a scientist as a man.*
.51	+	19. Men and women should be paid the same amount of money if they do the same scientific work. *19. Men and women scientists should be paid the same amount of money if they have the same kind of job.*
.30	+	20. Women should not have the same chances for advancement in science careers as men do. *20. Women scientists, like men scientists, should get more money the longer (amount of years) they work on their job.*
.37	+	21. Women should have the same educational opportunities as men. *21. Women should go to school as long as men do.*
.48	-	22. Women have less need to study math and science than men do. *22. Girls do not need to learn as much math and science as boys do.*
.46	+	23. We need more women in science careers. *23. We need more women scientists.*
.53	-	24. Men need more math and science careers than women do. *24. There should be more math and science jobs for men than for women.*
.53	-	25. It is better for a woman to study home economics than chemistry. *25. It is better for a woman to learn how to cook and sew than to learn science.*
.48	-	26. It is wrong for women to seek jobs when there aren't enough jobs for all the men who want them. *26. It is wrong for women to look for jobs when there aren't enough jobs for all the man.*
.53	+	27. A successful career is as important to a woman as it is to a man. *27. Doing well at work is as important for a woman as it is for a man.*

Alpha = .90 **Standardized Item Alpha = .90**

Table 2

Oneway Analyses of Variance (ANOVA) of Early Childhood Women in Science Scale (ECWiSS) Scores for Gender, Race/Ethnicity, Age/Grade, Socioeconomic Status, Household Structure, and School Sector with Ability as a Covariate

Source	ss	df	ms	F
Gender				
Between Groups	30.74	2	15.37	56.01***
Within Groups	135.63	494	.28	
Total	166.37	496	.33	
Race/Ethnicity				
Between Groups	11.22	5	2.24	7.08
Within Groups	155.82	492	.32	
Total	167.04	497	.34	
Age/Grade				
Between Groups	26.72	5	5.34	18.74***
Within Groups	140.32	492	.29	
Total	167.04	497	.33	
Socioeconomic Status				
Between Groups	11.64	2	5.82	18.90***
Within Groups	141.69	460	.31	
Total	153.33	462	.33	
Household Structure				
Between Groups	5.85	2	2.92	8.62***
Within Groups	136.73	403	.34	
Total	142.58	405	.35	
School Sector				
Between Groups	18.21	2	9.11	30.28***
Within Groups	148.83	495	.30	
Total	167.04	497	.34	

***$p \leq .001$

Table 3

Twoway Analyses of Variance (ANOVA) of Early Childhood Women in Science Scale (ECWiSS) Scores for Gender by Race/Ethnicity, Age/Grade, Socioeconomic Status, Household Structure, and School Sector, with Ability as a Covariate

Source	ss	df	ms	F
Gender	22.16	1	22.16	81.44***
Race/Ethnicity	2.23	4	.56	2.05*
Gender x Race/Ethnicity	1.15	4	.29	1.05
Error	132.23	496	.27	
Gender	22.12	1	22.12	94.92***
Age/Grade	18.99	4	4.75	20.37***
Gender x Age/Grade	3.34	4	.84	3.59**
Error	113.27	486	.23	
Gender	22.71	1	22.71	83.55***
Ability	6.71	2	3.36	12.36***
Gender x Ability	1.54	2	.77	2.83*
Error	133.44	491	.27	
Gender	22.60	1	22.60	86.23***
Socioeconomic Status	2.39	1	2.39	9.12**
Gender x SES	.05	1	.05	.66
Error	119.62	461	.33	
Gender	26.15	1	26.15	95.31***
Household Structure	.18	1	.18	.66
Gender x Household Structure	.33	1	.33	1.18
Error	109.75	400	.27	.33
Gender	22.92	1	22.92	89.57***
School Sector	9.71	1	9.71	37.95***
Gender x School Sector	.01	4	.01	.03
Error	125.89	492	.26	

* *p ≤ 1.0*
** *p ≤.05*
*** *p ≤ .001*

Table 4

Means and Standard Deviations for Full-Scale Early Childhood Women in Science Scale (ECWiSS) by Gender, Race/Ethnicity, Age/Grade, Socioeconomic Status, Ability, Household Structure, and School Sector (N=791)

Variable	M	SD
Gender:		
Male	2.76	.68
Female	3.16	.46
Race/Ethnicity		
Black	2.92	.61
White	3.25	.57
Hispanic	2.82	.55
Asian	2.97	.64
Other	2.90	.59
Age/Grade		
Kindergarten	2.62	.25
First	2.78	.39
Second	2.76	.56
Third	3.02	.68
Fourth	3.28	.57
Socioeconomic Status		
Eligible for *Free Lunch*	2.78	.55
Not Eligible for *Free Lunch*	3.37	.55
Ability		
Reading Below Grade Level	2.69	.63
Reading On Grade Level	2.87	.51
Reading Above Grade Level	3.01	.53
Household Structure		
Child Lives with Both Parents	3.02	.64
Child Does Not Live with Both Parents	2.86	.63
School Sector		
Student Enrolled in Private School	3.26	.46
Student Enrolled in Public School	2.57	.61

Table 5

Standardized Regression Coefficients for Predicting Attitude Toward Women in Science (ECWiSS) from Ability, Gender, Race/Ethnicity, Age/Grade, Socioeconomic Status, Household Structure, and School Sector (N=526)

	Early Childhood Attitude Toward Women in Science
Independent Variables	ß
Ability	.09 **
Gender	-.35 ***
Race/Ethnicity	-.03
Age/Grade	.10 **
Socioeconomic Status	.08
Household Structure	.04
School Sector	-.23 ***
R^2	.20
R^2_{adj}	.19

**$p \le .05$

***$p \le .001$

Table 6. *Early Childhood Women in Science Scale (ECWiSS) Items and Principal-Component Loadings*[*]

	Loadings					
Items	1	2	3	4	5	FUPC
1. Women can be good scientists just as men can be.	.69	.21	.47	.26	-.32	.64
2. Boys have more of what it takes to become a scientist.	.58	.32	.32	.16	-.62	.65
3. It is good for a woman to have a job as long as she is not the boss.	.07	.31	.14	.09	-.65	.41
4. Women scientists are weird.	.41	.15	.26	.39	-.69	.61
5. Girls can do important work in science.	.78	.17	.38	.31	-.36	.65
6. Work in science can be done just as well by men as by women.	.42	.20	.60	.20	-.19	.52
7. Women can't be counted on enough so they shouldn't have the most important jobs in science.	.32	.21	.38	.13	-.36	.58
8. Girls can be as good as boys in science and math.	.70	.13	.48	.41	-.34	.66
9. For a daddy to do well in his job is more important than for a mommy to do well in her job.	.11	.52	.31	.29	-.56	.55
10. The most important job a mommy can have is taking care of her children.	.26	.72	.08	-.05	-.27	.38
11. A lady scientist will not get along with her husband most of the time.	.20	.35	.45	-.05	-.47	.47
12. Both men and women can go to work and have families too.	.39	.13	.75	.18	-.28	.57
13. A mommy should work harder to help a daddy with his job than on her own job.	.09	.52	.47	.08	-.46	.51
14. Getting married should be the most important thing in a woman's life.	-.01	.67	.26	.15	-.32	.41
15. A woman should be able to get a job even when she is married and has children.	.30	.57	.63	.48	-.29	.56
16. For a woman it is more important to be a good wife and mommy than to be good at her job.	.15	.76	.07	.06	-.20	.35
17. A woman can be good at her job and be a good wife too.	.37	5	.59	.51	-.32	.59
18. A woman should be able to get the same kind of job as a scientist as a man.	.47	.27	.30	.61	-.33	.60
19. Men and women scientists should be paid the same amount of money if they have the same kind of job.	.33	.17	.55	.45	-.32	.58
20. Women scientists, like men scientists, should get more money the longer (amount of years) they work on their job.	.23	-.01	.55	.29	-.06	.37
21. Women should go to school as long as men do.	.28	.07	.26	.77	-.12	.44
22. Girls do not need to learn as much math and science as boys do.	.17	.42	.35	.40	-.40	.52
23. We need more women scientists.	.72	.16	.29	.32	-.19	.53
24. There should be more math and science jobs for men than for women.	.33	.42	.23	.29	-.58	.58
25. It is better for a woman to learn how to cook and sew than to learn science.	.22	.58	.24	.27	-.53	.56
26. It is wrong for women to look for jobs when there aren't enough jobs for all the man.	.16	.44	.51	.06	-.42	.51
27. Doing well at work is as important for a woman as it is for a man.	.43	.10	.41	.60	-.39	.60

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[*] N=671. 1=*Sex Role Identity* (eigenvalue = 7.9, percent of variance explained = 29.3, cumulative percent = 29.3), 2=*Home-Related Sex Role Conflict* (eigenvalue = 2.4, percent of variance explained = 8.8, cumulative percent = 38.1), 3=*Work-Related Sex Role Conflict* (eigenvalue = 1.2, percent of variance explained = 4.3, cumulative percent = 42.4), 4=Unamed (eigenvalue = 1.1, percent of variance explained = 3.9, cumulative percent = 46.4), 5=Unamed (eigenvalue = 1.1, percent of variance explained = 3.9, cumulative percent= 50.2). FUPC=first unrotated principal component. Based on the above loadings, it is recommended that the following 15 items be dropped from the 27-item ECWiSS: Items 3, 4, 6, 7, 11, 13, 15, 17, 18, 21, 22, 23, 24, 25, and 27.

Figure 1

*Analytical Model to Test the Universalism in Science Hypothesis: Partial Relationships between Ascription and Attitude Toward Women in Science with Merit Held Constant**

	MERIT (Ability)			
	High Ability		Low Ability	
	ASCRIPTION (Sex)		ASCRIPTION (Sex)	
Attitude	Male	Female	Male	Female
Positive Attitude				
Negative Attitude				
Total				

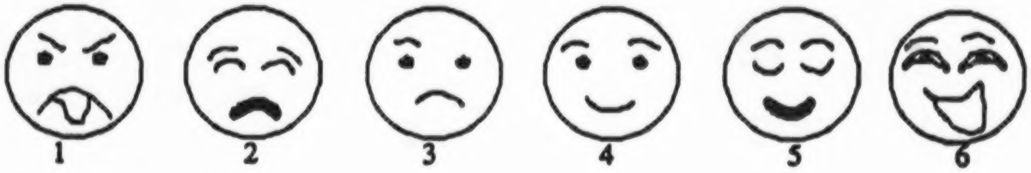
**Ascription* is not related to *attitude* if the same percentage of people of both sexes have positive attitudes. If the percentages change when the cases are divided into high and low ability, the differences in perctanges are attributed to *merit*.

Figure 2

Response Item from Original and Revised Versions of the Early Childhood Women in Science Scale (ECWiSS)

Original 6-point Scale Form

8. Girls can be as good as boys in science and math.



Revised 4-point Scale Form

8. Girls can be as good as boys in science and math.

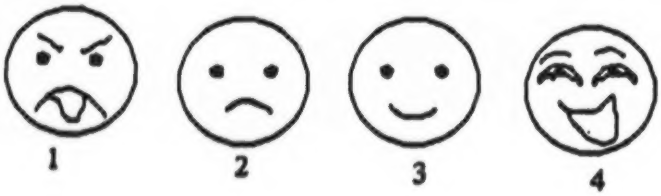


Figure 3. *Mean Ratings of Attitudes by Gender, Race, and SES with Ability Controlled*